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PRACTICAL RADIO

AND

ELECTRONICS COURSE

VOLUME THREE

Applied Electronics and Radio Servicing

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LESSON 23

The Field of Electronics

ECONOMICS OF THE INDUSTRY. It is hard to realize that Electronics in 1943, was a four billion dollar industry—more than the whole pre-war U. S. automobile industry. Even more striking is the comparison of the last year activity in the Electronic field with this industry in 1942, when it was only a one billion dollar a year business. What constitutes the field of Electronics and where does its future lie?

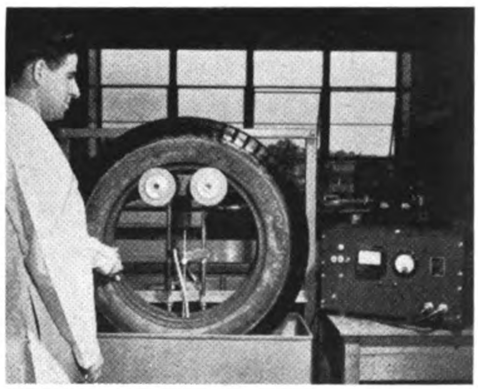
Courtesy U. S. Signal Corps and Institute of Radio Engineers

Figure 302. Radio communications is an important branch of Electronics. This illustration shows the use of mobile radio in warfare.

THE FIELDS OPEN TO ELECTRONICS. Radio, television, facsimile are the usual fields associated with electronic vacuum tube circuits. But electron tubes with their moving and easily controlled electron streams are being used in conversion of power, in industry for testing, measuring, timing, and production, in medicine for diagnosis and treatment, in scientific research, and in long range detecting. New developments in electronic circuits will bring improvements in these applications and will suggest thousands of new and unforseen uses. Electronics will bring a change and unexpected improvement in communication and transportation.

THE ELECTRON, VACUUM TUBE, AND ELECTRONICS. An electron in keeping its orbit and place within an atom proves of little interest to the practical man. Electrons become more interesting when they assume the freedom to move along a conductor, forming electric current. It is in a vacuum tube, however, where electrons move as free bodies, directed and attracted by the geometrical shape of the elements and the potentials placed upon these tube elements, that they become the back-bone of Electronics. The diode

The opportunities in the fields of Electronics and Radio are increasing. Because basic knowledge and training are required for all types of work in these fields, the jobs are interesting and the salaries are higher than in other *mechanical* occupations.



Supersonic vibrations, or audio frequencies above the hearing range, are used to detect defects in used automobile tires with the aid of a new electronic device perfected by scientists of the *Goodyear Tire & Rubber Co.* Many new industrial applications are found for electronic devices every day.

TYPES OF ELECTRON TUBES

You should begin to think of electron tubes as devices which can be used to rectify, amplify, generate, permit light to control electric current, and produce light under the influence of electricity as in cathode ray tubes.

and triode tubes were designed for and first used in radio. But these simple vacuum tubes and others developed later for certain specific purposes are used today in thousands of diversified applications, many very far removed from radio and communications.

Electronic tubes may be divided into the vacuum types and the gas-filled types. We have already studied about *radio receiving* type tubes and their associated *radio* circuits. We have learned that transmitting type tubes are similar but larger and sometimes water cooled. We also had an introductory explanation of photo-electric cells and cathode ray tubes. Later lessons in this Volume 3 of the *course* will introduce us to other tubes such as the thyratron and klystron.

The possibilities of future electronics lie in changing electric current, transmission of power without wires, more exacting control and measurements, weather forecasting, medical research, automatic analysis of complex gases, flight control, and great improvement in communications.

Courtesy Consolidated Vultee Aircraft Corp.

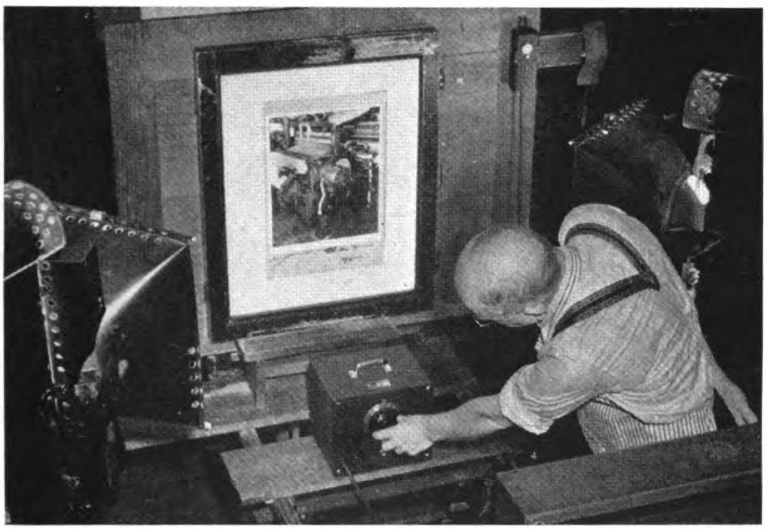
Figure 303. In realizing that the airplane has made the world more closely coordinated, you must remember that long distance flights are possible only with the aid of radio and electronic equipment.

LESSON 24

Photo-Cell Equipment

Application of Photo-Cell Equipment. The photo-electric cell and the associated equipment can be employed to *see* more accurately than the human eye and respond more quickly than the human hand, and to do so continuously, unfalteringly, at all times. With unerring precision, photo-cell equipment can be made to signal, grade, match, compare, start, stop, count, control, and time. The mysteriously swinging doors, automatic sorting devices, safety controls on punch presses, burglar alarms, blackout light controls, combustion controls are just a few modern applications of electronic photo-cell devices. Photo-cell equipment is also used for color matching, comparing opacity of materials, window light control, and highway speed timing.

Many devices using photo-electric cells and performing various industrial services could not be replaced with any other equipment or merely by an operator. While in many applications, photo-cell equipment replaces other means of doing the same job and offers some advantage of accuracy, speed, or reduction of cost; in many instances, photo-cell equipment is unique in its ability to perform the task required.



Courtesy "Radio News" Magazine

Figure 304. Photo-cell equipment is used for proper adjustment of lights and camera setting for best photographic results.

Additional Information About Photo-Cells. We have already learned in Lesson 9, that a photo-electric cell is a light sensitive tube in which the sensitive surface emits electrons under the influence of light. In the usual cell, the cathode surface which emits the electrons and the anode which is connected to a source of positive potential are enclosed in a glass envelope from which air is removed. Sometimes, to increase the sensitivity of the cell, inert gas at low pressure is pumped into the bulb.

Extensive information on the photo-cells used in commercial units is purposely omitted. Detailed information on commercial photo-cell tubes is available from the manufacturers of the units.

The cathode is usually a concave (rounded) surface on which the light sensitive material has been deposited. The anode takes the form of a centrally located wire which attracts and collects the electrons emitted from the cathode. The number of electrons emit-

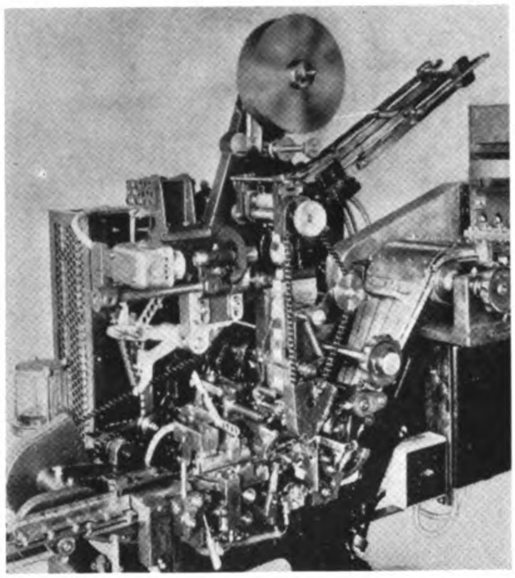
RESISTANCE OF A PHOTO-CELL

To think of the photo-cell as a variable resistor is especially advantageous in analyzing the action of circuits.

The subject of *illumination* may be looked up in a text-book on Physics or in an Encyclopedia.

There are many other practical circuits which employ a photo-cell and a single amplifier tube. Two or more stages of amplification could also be employed. The photo-cell shown in this circuit requires a polarizing voltage of 90 volts.

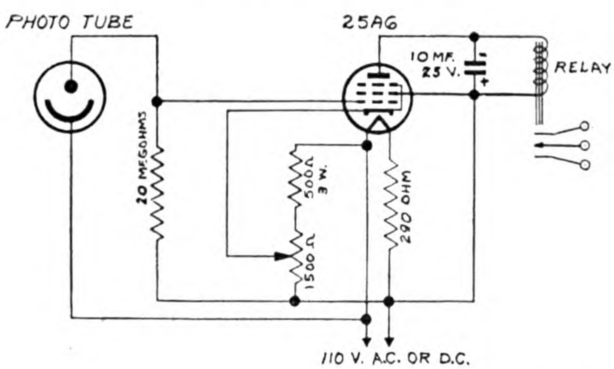
ted and forming the photo-electric current to the anode is a function of the light falling on the cathode surface. The student may also consider the photo-cell as being a variable resistor with a value of resistance dependent on the light falling on the cathode surface. In the dark, the equivalent resistance is very high, while with strong light the resistance is greatly reduced. A typical cell with light of 5 foot-candles*, under normal operating conditions, has the equivalent resistance of almost 100 megohms. With 70 foot-candles of illumination, the resistance corresponds to 10 megohms.



Courtesy "Radio News" Magazine

Figure 305. Cellophane wrapping machine using a photo-electric relay to synchronize the cutting and printing.

A Simple Photo-Cell Unit. In order to introduce you to a complete photo-cell unit, we will describe a simple practical circuit which can be operated from 110 volts A.C. or D.C. and employs a type 25A6 pentode as the amplifier and rectifier.



Courtesy Allied Radio Corp.

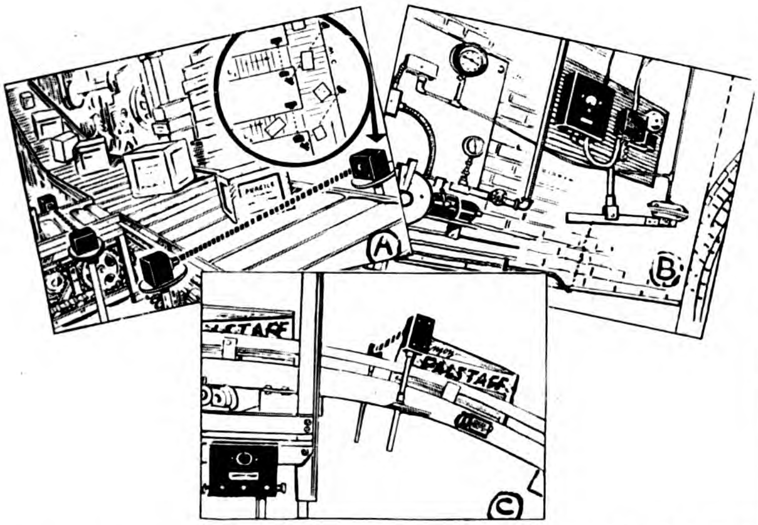
Figure 306. A circuit of a simple photo-electric relay using a single tube for an amplifier. This unit may be operated from a 110 volts A.C. or D.C.

*A foot-candle is the amount of light received from a standard candle at a distance of one foot.

Consider the circuit at the point where a positive potential* exists on the side of the line connected to the relay and screen grid of the 25A6 tube. If the control grid of this tube is not biased to a cut-off point, a certain amount of current will pass through the plate circuit and activate the relay. The actual bias of the grid will depend on the internal resistance of the photo-tube and also on the setting of the potentiometer.

With the photo-cell receiving a definite amount of light, the potentiometer may be adjusted so that the plate current is just below the point where the relay will have sufficient energy to pull down the armature.

Now, if the source of light is reduced, the internal resistance of the photo-tube will rise and cause a higher positive potential to be applied to the grid and counteract the negative potential obtained through the drop in the potentiometer circuit. The net rise of the control grid voltage will cause the additional plate current to pass and the armature to move down to the magnet pole. Since the armature has a contact on each side, it will make another circuit and break the one previously made. In this manner, equipment associated with the photo-cell unit may be started or stopped with the increase or decrease of light.



Courtesy Worner Products Corp.

Figure 307. The control of conveyors can be easily accomplished with photo-cell equipment. Illustration A. Boxes of all sizes may be sorted. In B, you have a view of an installation controlling a furnace to give proper combustion. Packages on a conveyor belt may be easily counted with photo-cell equipment, as illustrated in C.

Practical Installations. Let us consider a few exact uses for photo-cell equipment. A simple photo-cell unit may be used to turn on lights at dusk and possibly turn these lights off after daybreak. Since sundown-time changes each day, this type of installation will insure correct time for switching on the lights and will prevent waste of electric power.

When improper combustion occurs, excessive smoke is present. By placing a photo-cell relay unit and a light source facing each other inside the chimney, excessive smoke will be instantly detected,

*When the negative potential exists at this point (during each half cycle in A.C. operation), the unit is not operating and the condenser across the relay acts as the time delay.

CIRCUIT EXPLANATION

Observe that the 1,500 ohm potentiometer and the 500 ohm resistor are connected in series across the 110 volt line. The photo-cell and 20 megohm resistor are also connected across the line. For any one light condition, the photo-cell will have a definite *resistance* and the line voltage will furnish some value of potential at the junction connected to the control grid of the 25A6. The setting of the 1,500 ohm potentiometer permits the adjustment of the potential on the cathode to be higher or lower than this grid voltage. In this manner, a condition (grid voltage) for proper operation can be selected to meet the requirements imposed by the light falling on the photo tube.

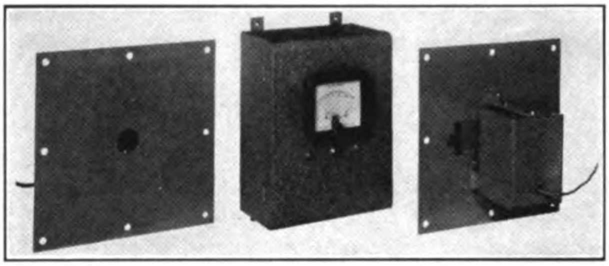
Two or more photo-cell units may be so connected that certain operation occurs only if both are energized in a certain order.

It is important for you to understand that a photo-cell unit may be used to sound an alarm, count, permit or prevent an operation, start or stop an action, measure light intensity, indicate color, and that all of these operations really are nothing more than the control of electrical circuits which may perform these operations.

Color or shape of boxes may also be used as the factor for operating the sorting equipment.

and associated electrically operated equipment can carry out the adjustment of the furnace controls.

Sorting of various size boxes can be easily accomplished. The smaller boxes may not interrupt the light beam, while the larger boxes will. Counting of items which pass in front of the equipment is carried out in the manner illustrated. The relay operates an electric counter in such applications.

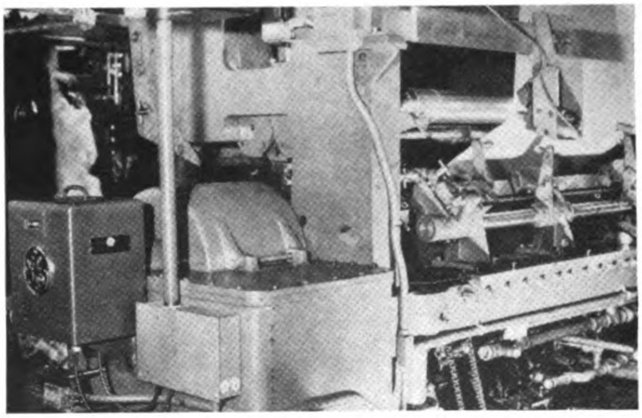


Courtesy Worner Products Corp.

Figure 308. These three units make up the equipment needed to supervise and control combustion. The light source, shown at the left, and the photo-cell at the right, may be mounted in the chimney, while the control cabinet is placed near the furnace to be controlled.

Another application exists in a restaurant which has several tables placed near the wall. A narrow beam of light is projected parallel with the wall about 30 inches above the table tops. At the opposite end, the beam strikes the lens of a photo-cell unit. Any person sitting at one of these tables can interrupt the beam of light by merely raising his hand. This can cause an alarm bulb to flash and inform the waiter that he is wanted at one of the tables.

In connection with printing presses, photo-electric equipment is used to assure proper register; i.e., proper position of the different colors on the printed page. The machinery will be stopped automatically and an alarm will sound if the register is not correct.



Courtesy "Radio News" Magazine

Figure 309. Photo-electric color register control for multi-color gravure press. View of drive side, showing complete color-unit equipment.

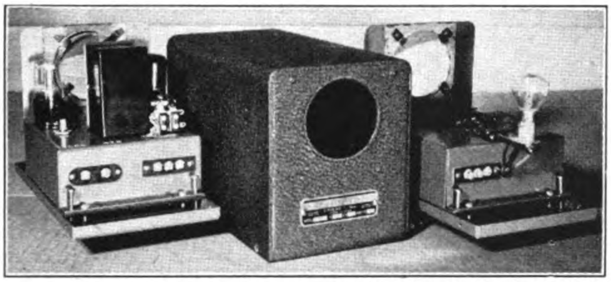
When infra-red light source is used, a photo-cell is selected which has high sensitivity to the wavelength of this light.

During the War period, photo-cell equipment can be used for anti-sabotage purposes. The system can be made to fit any requirement and provides fullproof protection which cannot be bribed. Usually the light source provides a beam of invisible infra-red light, projected towards the photo-cell unit. When this light beam is interrupted, the relay of the photo-cell unit is actuated and, in turn, operates an alarm. The alarm may consist of bells, lights, or sirens, and may be local or may be connected directly to the police headquarters.

Technical Considerations. You must bear in mind that the distance covered by any photo-cell installation depends upon the power of the light source, the sensitivity of the relay, and the light conditions present. At all times, in a darker place, a given amount of light and a definite type of photo-cell unit will operate over a much longer distance. The presence of stray light or a strong nearby illumination will considerably decrease the sensitivity of the equipment.

INSTALLATION SUGGESTIONS

Stray light may be eliminated or reduced with a suitable visor or shield.



Courtesy Worner Products Corp.

Figure 310. The light source and photo-cell amplifier are shown outside of the weatherproof case. This system is designed especially to serve as a guard and protect life and property against sabotage.

Several interesting photo-cell installation lay-outs are illustrated in this lesson. These examples will help you understand the application of photo-cell equipment and design other installations for some special requirements. Notice that the light can be directed at the photo-cell unit, or it can be reflected at several angles with the aid of mirrors. The angle formed by the beam of light striking the mirror and by the beam being reflected, should never be greater than 90 degrees for good results.

The reflecting mirror should be placed in a position where stray light will not be reflected.

A lens is employed at the light source to concentrate the light from the bulb into a straight beam. The bulb may be an automobile headlight type since it has a suitable small filament. Another lens may be used with the photo-cell to collect the incoming light and focus it on the cathode surface of the cell.

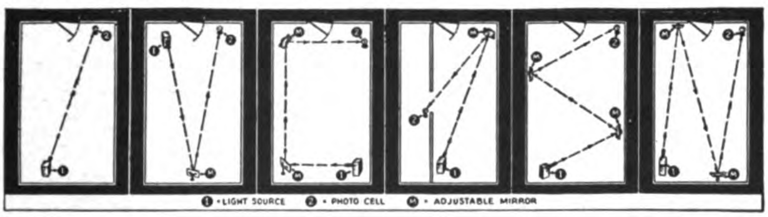


Figure 311. Suggestive installations using a single light source and photo-cell unit. With the aid of mirrors the path of the light can be controlled.

Hints for Servicing Units. As a simple test, place any suitable light source near the photo-cell relay unit, and turn the sensitivity adjustment until the relay just *clicks*. Now *back-up* with the control until the relay is returned to its natural position. The removal of light, or even a decrease of the light intensity, should immediately cause the relay to click again. This test, of course, is performed on the type of unit which has its circuit designed to close the relay with a *decrease* of light. For photo-cell units which close the circuit with an increase of light, the same test should be performed in darkness, whereupon flashing a light on the photo-cell will cause operation.

The usual photo-cell unit uses such a simple circuit that you will be able to trace it out in a matter of minutes. By following the service suggestions given, we are confident you will be able to repair successfully any faulty photo-cell device.

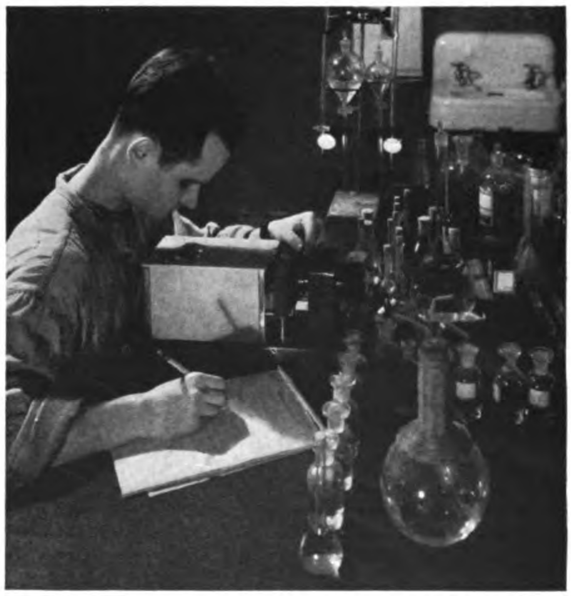
Courtesy Central Scientific Company

Interior view of the *Photelometer* showing the sensitive microammeter with lamp for illuminating its scale. The adjustment for precise setting of the meter pointer is on the right-hand panel of the housing. The photo-cell is located within the holder which is held in place under pressure of the springs on its support rods.

If too much light change is needed to cause the operation to take place, probably the difficulty lies in the photo-cell or the amplifying tube employed, and these should be replaced as the first test. If no operation at all is obtained, the power is not coming from the line; or some resistor or other associated part of the circuit is at fault. Since only one or two resistors and one or two condensers are employed in the usual circuit, these can be easily checked or replaced for testing purposes.

Photo-Electric Pyrometer. The photo-electric pyrometer is employed for indicating, recording, and controlling associated apparatus, in the process of working on hot incandescent bodies. The radiant energy from a hot body (molted metal, hot steel bars, etc.) is directed to the photo-cell of the device and causes it to pass current which bears a definite relationship to the temperature of the hot body. This current is amplified by a stable vacuum tube amplifier and the amplified current, in turn, is passed through the indicating or recording instrument, or is used to control and adjust associated equipment.

Photelometry Applications. A *photelometer* evaluates the concentration of a solution by the deflection of the pointer of a sensitive meter; the amount of deflection depends upon the light transmittancy of the solution under test. By a comparison to standard records valuable chemical tests can be quickly made. A suitable photo-cell, of course, is used in this practical scientific tool.



Courtesy Central Scientific Company

Figure 312. Photo-cells find many unusual applications. The photograph shows a chemist preparing a *Photelometer* for chemical solution analysis.

Review Questions and Problems. 1. Can you name several additional applications of photo-cell equipment not mentioned in the text of the lesson?

2. Can a photo-cell, sensitive relay, and a suitable battery be connected in series to serve as a photo-cell unit? Would this circuit have serious limitations? How about advantages?

3. How can stray light be kept away from the photo-cell?

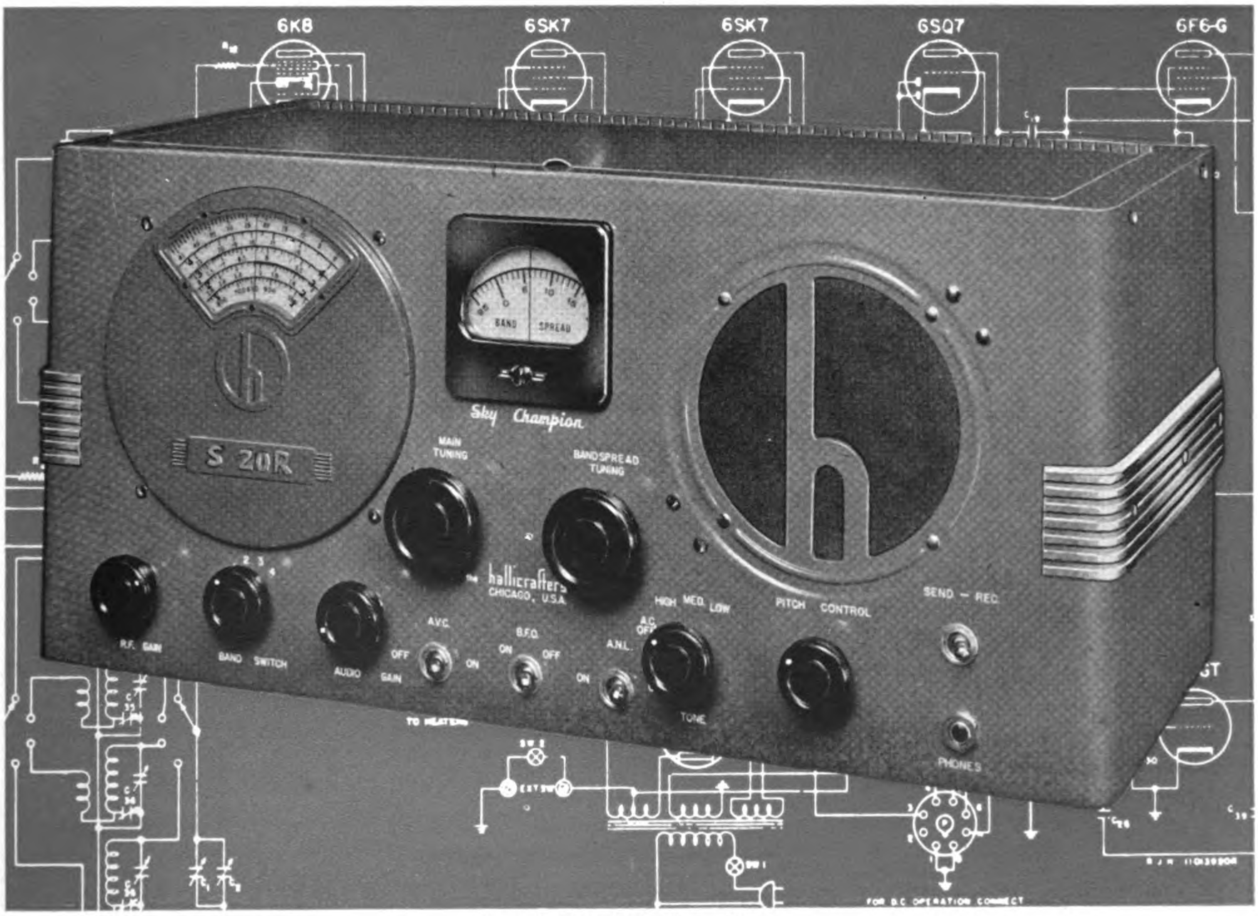
4. Name a few possible faults which could develop in a photo-cell unit.

LESSON 25

Communications Equipment

Purpose of Communication Receivers. The usual home radio receiver is employed for the purpose of receiving entertainment, news, and educational programs. From the explanation given in Lesson 14, you know that a good communication receiver may be used for this purpose also. But a communication receiver is intended to do more than this. There is greater interference on the bands used for commercial and amateur radio communications, the transmitters are located at considerable distances apart in many cases, and the message must be received under every atmospheric condition. Further, communication receivers are usually employed on locations where two way communication is carried on.

This lesson was prepared with the aid of *The Hallicrafters, Inc.*, whose various communication receivers and transmitters are used to illustrate this type of equipment.



Courtesy The Hallicrafters, Inc.

Figure 313. A medium size communication receiver which provides four band reception.

BASIC FEATURES OF THE S-20R.

THE HALLICRAFTERS S-20R RECEIVER. The communication receiver illustrated is a medium-size unit. We will briefly describe this receiver and point out certain features not found on home-type radio sets.

Many broadcast receivers permit reception on several bands, but do not give complete coverage furnished by the better communication receivers.

Nine tubes are employed in this four band receiver which covers 545 KC. to 44 MC. completely. By referring to the front view, you will notice that an R.F. GAIN control is incorporated besides the AUDIO GAIN control which corresponds to the volume control of a regular radio. A beat frequency oscillator, BFO, is included and is essential for receiving telegraph (C.W.) signals. The pitch of the resulting *beat* may be varied with a control placed under the loudspeaker.

A pitch of a certain frequency may be most pleasing and easily audible for the operator.

The automatic volume control circuit may be eliminated from operation by placing the AVC switch in the OFF position. AVC is not used when receiving code. At the right hand end of the panel there is a SEND-REC switch which breaks the plate voltage circuit during the transmit periods. The knob which controls the A.C. line switch also serves as a three position tone control. Locate these controls as you read about them.

The receiver is made inoperative while a separate transmitter is used to send out messages.

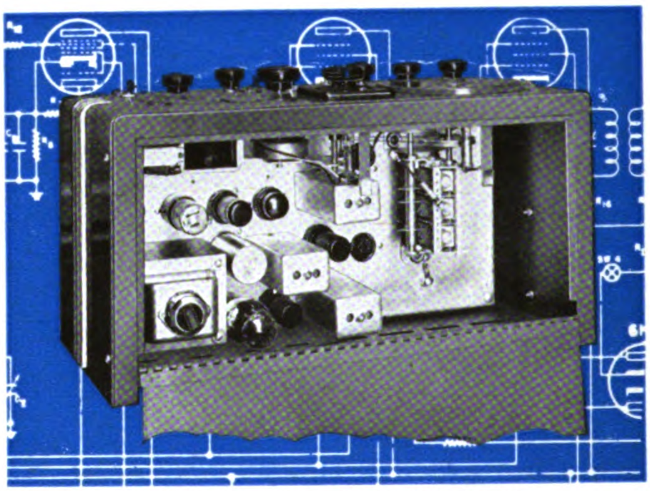


Figure 314. A top view of the chassis of the *Hallicrafters* model S-20R receiver. Notice the single plates in each gang of the tuning condenser which are employed for bandspread tuning.

BANDSPREAD TUNING. Since many of the stations on the short-wave bands use frequencies adjacent to those of other stations, extra selectivity is obtained with an R.F. stage and the tuning process is simplified with bandspread. A large, easy-to-read dial is calibrated for the four bands and is turned at a reduced rate with the MAIN TUNING control. A single plate of each gang of the variable condenser is placed on a separate shaft, and these equivalent small parallel condensers are controlled by the knob marked BANDSPREAD TUNING. Very fine degree of adjustment is possible with the bandspread control.

This method of obtaining bandspread is different than the method we studied in Lesson 14.

CIRCUIT CONSIDERATIONS. The majority of communication receivers incorporate one or two R.F. preselector stages. The circuit, of course, is of the superhet type with two stages of I.F. An I.F. of about 456 KC. is used in many of these sets. Additional circuit refinements, which will be described later, are included to give the best possible operation.

ADVANCED TYPE COMMUNICATION RECEIVER. The *Hallicrafters* model SX-28 receiver illustrated is the last word in communication receivers design and will be of interest to you as a future radio technician or operator. Examine the controls of this receiver as shown in the illustration below and compare these with the ones included for the model previously described and the communication receiver explained in Lesson 14.

This receiver will tune from 550 KC. to 42 MC. in six bands. Each band overlaps the adjacent ones, so that stations operating on frequencies which are received near the end of any one band, may also be received on the next band.

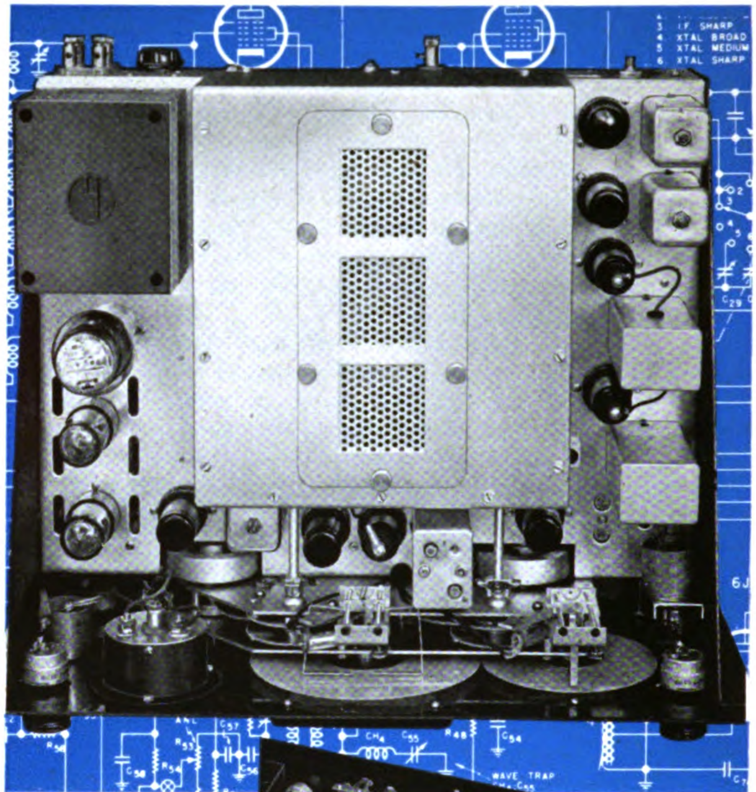
The knobs of a good quality communication receiver are easy to grip and convenient to hold. The control knobs are located to give good visibility and convenience of operation. Imagine yourself sitting in front of the receiver illustrated and try *to see* how easy it is to reach and turn the various controls.

Refer to page 218, of Volume 2, and see what amateur bands can be received on this receiver. Does it include the American broadcast band?

Notice the use of metal tubes. Glass tubes are used in the audio stage and power supply.

To align a complex receiver of this type, detailed instructions giving the position of the trimmers and padders will be needed. A good signal generator, capable of furnishing the various frequencies covered by this receiver, will also be required.

The variable condensers are mounted on floating rubber supports. Nearby vibrations will not upset any previously made tuning adjustment.



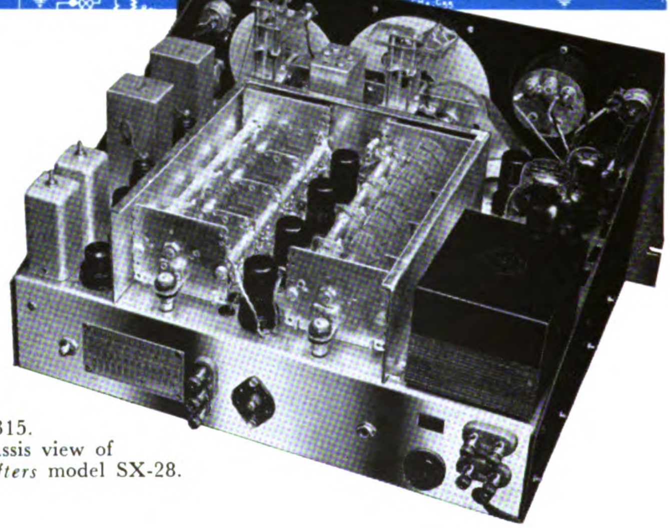


Figure 315.
Top chassis view of
Hallicrafters model SX-28.

Placement of Parts. Good engineering design permitted the placement of parts to aid in making the connections short and direct. The four metal tubes placed between the main tuning condenser and the band-spread condenser, are used in the two R.F. stages, oscillator, and mixer. Metal tubes, of course, are self-shielded, but the added shield over the tubes and tuning condensers eliminates all possibilities of picking up stray signals. The power supply and audio section are on the right (rear view), while the I.F. stages are at the left.

CRYSTAL FILTER CIRCUIT. When the switch shown in the schematic is in positions 1, 2, and 3, the crystal circuit is short circuited. In position 4, with the transformer T_2 tuned to the crystal frequency, a relatively broad resonance curve is obtained. In position 5, the trimmer C_{29} is adjusted for the circuit to provide selectivity midway between the previous adjustment and CRYSTAL SHARP setting. For position 6, the trimmer C_{30} is adjusted to obtain the sharpest crystal action. Under this condition, the secondary of T_2 is slightly detuned from the crystal frequency. This detuning prevents the secondary resonance curve

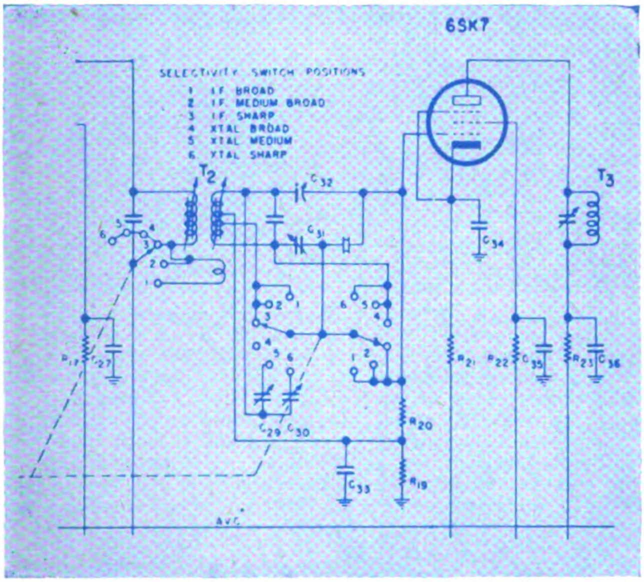


Figure 316. Circuit of the crystal filter used in *Hallicrafters* SX-28 receiver.

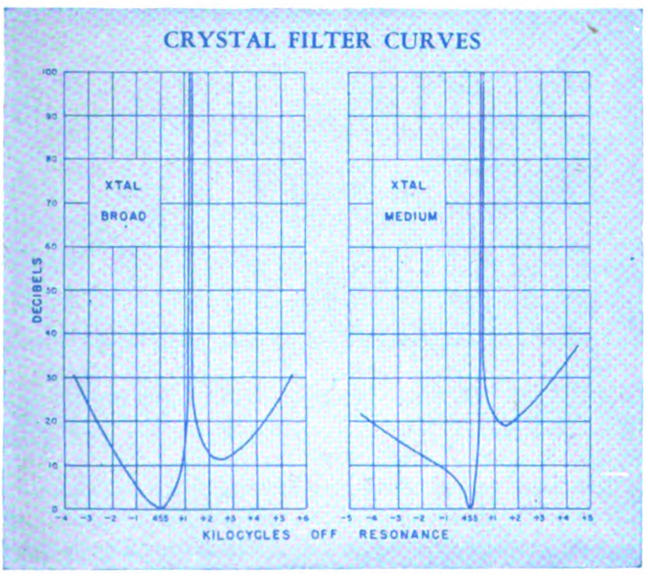


Figure 317. The action of the crystal for the different settings is apparent from the response curves shown.

EXPLANATION OF THE CIRCUIT

This explanation should be followed with care by referring to the diagram of Figure 316.

The switch shown in this schematic is operated in conjunction with an additional gang of the preceding stage. These various circuits are switched with the same rotation.

The crystal filter is used in conjunction with the I.F. of 455 KC. The base line of each graph is calibrated in kilocycles off this frequency which represents resonance. The vertical scale shows the loss (in decibels) introduced because of the crystal action.

This interference will result only if a powerful or nearby station is transmitting on a frequency very near the frequency of the station to be received.

from being greatly affected by the crystal, but the secondary is still coupled tightly enough so that a transfer of energy to the crystal takes place.

SINGLE SIGNAL RECEPTION. When a communication superhet is used to receive code and the BFO is employed, the frequency of the BFO is adjusted to produce the desirable pitch when beating with the signal of the wanted station which may have its frequency below that of the BFO. But the same BFO frequency will beat with a station which may have its frequency correspondingly above and interference will result. Single signal adjustment possible with the better communication receivers will eliminate this problem. The figure explains the technique.

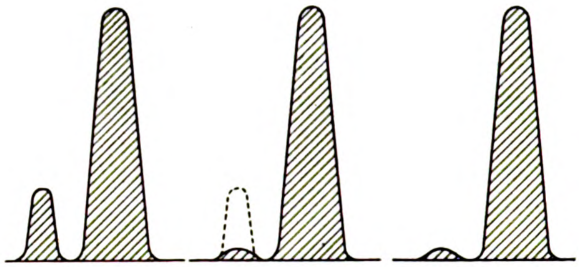


Figure 318. Effects resulting while carrying out single-signal adjustment. The curves at the left are obtained with the selectivity switch in the X'TAL SHARP position and are used to identify the weaker amplitude. The receiver is tuned to the weaker amplitude. In the next graph, the effect of adjusting this weaker amplitude to a minimum value with the phasing control is shown. As a final adjustment, graphically shown at the right, the receiver is retuned to the stronger amplitude and then the pitch control of the BFO is adjusted for a pleasing note.

The AVC action varies somewhat at different frequencies of operation.

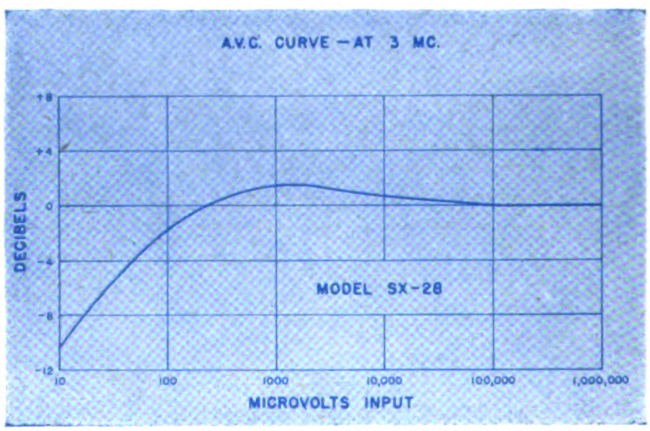
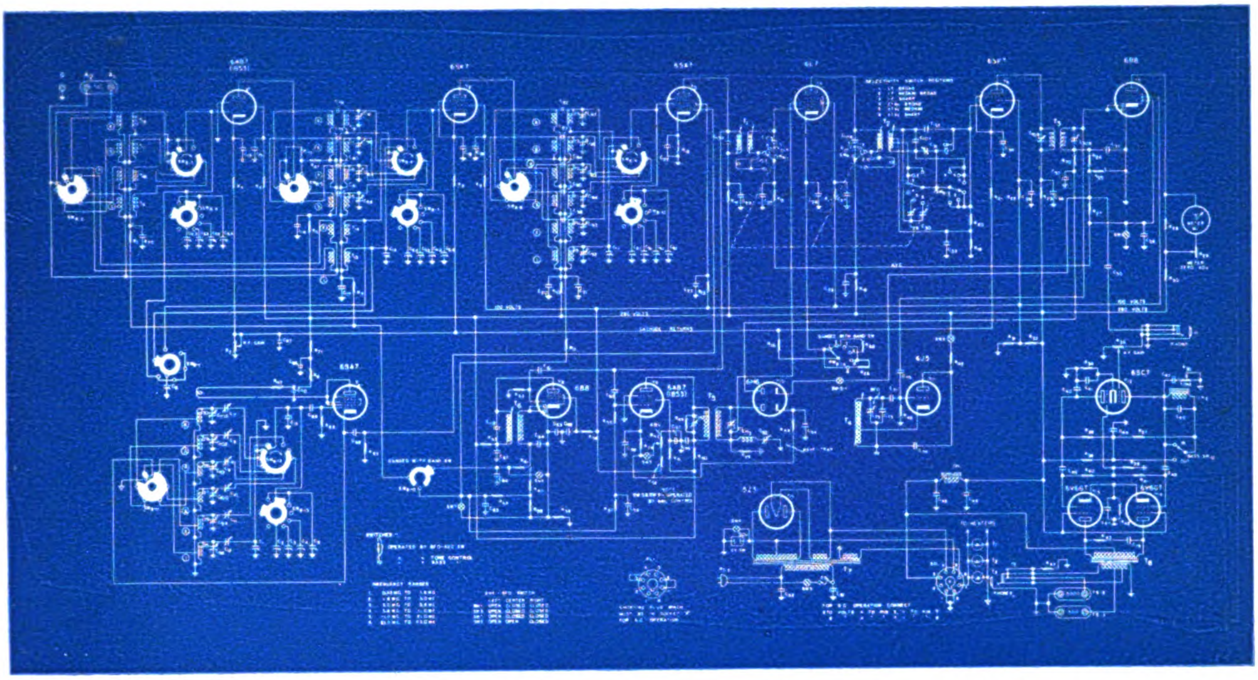


Figure 319. The action of the AVC is shown by the graph.

UNUSUAL AVC ACTION. A double AVC system is employed. The R.F. and mixer tubes are *operated* by the broadly tuned carrier passing through only three tuned I.F. circuits. The final signal, however, passes through six tuned I.F. circuits. As a result, when the signal is slightly detuned, the receiver output has dropped considerably while the AVC action has dropped but little. This results in a reduction of between-station noise and a more sharply defined aural tuning action.



FIXED CONDENSERS

C_{14}, C_{15}, C_{18}, C_{19}, C_{22}, C_{23}, C_{27}, C_{33}, C_{35}, C_{39}, C_{50}, C_{57}, C_{62}, C_{65}	.02 mfd., 400 v.
C_{16}, C_{20}, C_{24}, C_{28}, C_{36}, C_{42}, C_{56}, C_{67}	.02 mfd., 600 v.
C_{17}, C_{21}, C_{26}, C_{34}, C_{53}, C_{58}, C_{63}, C_{66}, C_{77}	.05 mfd., 200 v.
C_{25}, C_{70}, C_{76}	2,000 mmfd., mica
C_{37}, C_{60}, C_{68}, C_{69}	50 mmfd., mica
C_{38}, C_{79}, C_{80}, C_{83}	5-6½ mmfd. ceramic
C_{40}, C_{86}	500 mmfd., mica
C_{41}	40 mfd., 25 v.
C_{43}	5,000 mmfd., mica
C_{44}	10 mfd., 300 v.
C_{45}, C_{46}, C_{54}	.05 mfd., 400 v.
C_{47}	40 mfd., 25 v.
C_{48}	30 mfd., 400 v.
C_{49}	30 mfd., 450 v.
C_{51}, C_{52}, C_{74}	.01 mfd., 600 v.
C_{61}	250 mmfd., mica
C_{64}, C_{71}	100 mmfd., mica
C_{73}	500 mmfd., silver mica
C_{75}, C_{81}, C_{84}, C_{85}	Twisted leads, 2 mmfd.
C_{78}, C_{82}	10 mmfd., ceramic
C_{87}	.25 mfd., 200 v.

RESISTORS

R_1, R_7, R_{11}, R_{15}, R_{19}, R_{24}, R_{36}, R_{37}, R_{48}, R_{57}, R_{59}, R_{69}	100,000 ohm, ½ w.
R_2	10,000 ohm, pot.
R_3, R_8, R_{14}	300 ohm, ½ w.
R_4	25,000 ohm, ½ w.
R_5, R_9, R_{13}, R_{17}, R_{22}, R_{34}, R_{56}	1,000 ohm, ½ w.
R_6	6,800 ohm, 2 w.
R_{10}, R_{18}, R_{23}, R_{63}	3,000 ohm, ½ w.
R_{12}	400 ohm, ½ w.
R_{16}	270 ohm, ½ w.
R_{20}, R_{25}, R_{27}, R_{55}, R_{61}, R_{62}, R_{64}	500,000 ohm, ½ w.
R_{21}	250 ohm, ½ w.
R_{26}	1,800 ohm, ½ w.
R_{28}	110 ohm, ½ w.
R_{29}	500 ohm, ½ w.
R_{30}	27,000 ohm, ½ w.
R_{31}	11,000 ohm, 1½ w.
R_{32}	4,000 ohm, 7 w.
R_{33}, R_{35}	500,000 ohm, pot.
R_{38}, R_{46}, R_{52}, R_{65}, R_{66}	50,000 ohm, ½ w.
R_{39}	200,000 ohm, ½ w.
R_{40}, R_{41}, R_{60}	250,000 ohm, ½ w.
R_{42}	220 ohm, 2 w.
R_{43}, R_{45}	20,000 ohm, 2 w.
R_{44}	5,000 ohm, 10 w.
R_{47}	8 ohm, ½ w.
R_{49}, R_{70}	1 megohm, ½ w.
R_{50}, R_{67}, R_{72}	500 ohm, ½ w.
R_{51}	20,000 ohm, 1 w.
R_{53}	50,000 ohm, pot.
R_{54}	35 ohm, ½ w.
R_{58}	200 ohm, ½ w.
R_{68}	1,200 ohm, ½ w.
R_{71}	5,000 ohm, 1 w.

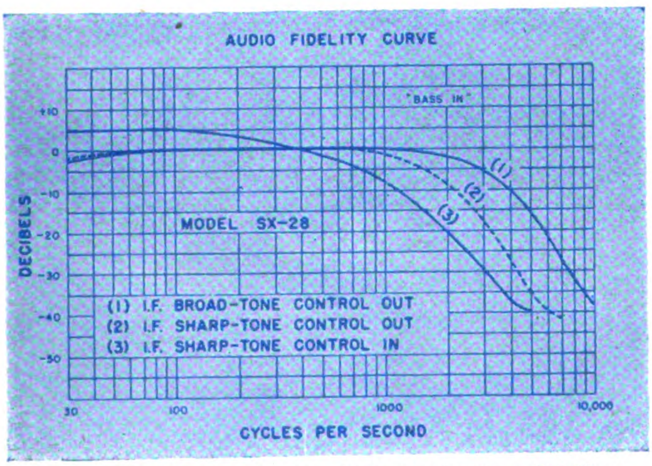


Figure 320. Audio response of the *Hallicrafters* SX-28 receiver with different adjustments. Almost flat response is obtained between 30 and 2,000 cycles, and a small drop occurs for higher frequencies.

Audio Response. A pair of 6V6 tubes in push-pull is used in the final audio stage of the SX-28, and an undistorted output of 8 watts can be obtained. As shown in the graph, very good response curve is obtained with I.F. in the BROAD position and the tone control out.

The block diagram shows the similarity of a FM and AM circuit. Besides the detectors being different, the band width of the I.F. amplifier is changed (made broader) for FM operation.

Combination FM and AM Receiver. With the exception of the detector circuit, frequency modulation and amplitude modulation receivers are very similar. For operation in the ultra-high frequency band, the various stages of FM and AM receivers are alike and only the detector need be different for each type of modulation. *Hallicrafters* engineers took advantage of this fact in designing model S-27 receiver. As indicated in the block diagram, the same R.F., mixer-oscillator, I.F., and audio stages are used for both types of reception, but the circuit is switched from one type of detection for FM to the type needed for amplitude modulation.

This receiver provides for reception of three bands covering 28 to 46 MC., 45 to 84 MC., and 81 to 145 MC. Acorn tubes are used in the R.F. stages and converter.

Because the receiver is intended for receiving ultra-high frequencies, the I.F. is 5.25 MC. The use of iron core coils in the I.F. amplifiers gives very high Q and allows sufficient station discrimination on the 10 meter communication band. The response may be broadly expanded for proper reception of frequency modulation signals by a turn of the selectivity switch.

The output of the I.F. amplifier feeds both the AM and FM detectors. An additional sharply tuned I.F. stage precedes the AM diode detector, however, to provide the necessary selectivity and additional gain. The FM detector system includes a limiter which serves as an amplifier when the signal is weak, but prevents the amplitude from rising beyond a fixed limit when the signal increases.

Figure 321. A combination frequency modulation and amplitude modulation receiver. This set will tune from 28 to 145 MC. on the ultra-high frequencies.

A PORTABLE COMMUNICATION RECEIVER. *Hallicrafters* receiver model S-29, known as "The Sky Traveler," inbodies many of the features of large communications receivers and yet is sufficiently small and light for easy portability. The receiver may be operated from the self-contained batteries or from 110 volts A.C. or D.C. Four band reception is incorporated giving coverage from 550 KC. to 30.5 MC.

Examination of the front panel shows the usual controls found in communication receivers. Bandspread is included. The loud-speaker is mounted on a side panel. Alongside the speaker opening is a headphone jack. When a phone-plug is inserted, the speaker is automatically disconnected.

CONTROLS AND CIRCUIT DETAILS. Starting at the left of the front panel, the various controls and their functions will be described. The ANL switch connects the noise limiter circuit and effectively minimizes ignition and similar types of interference.

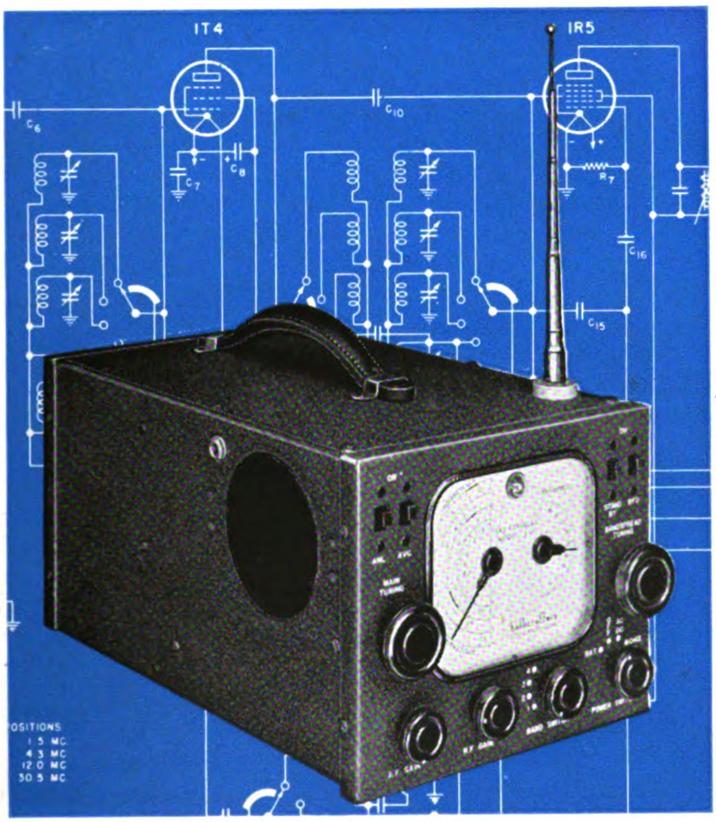


Figure 322. The *Hallicrafters* SKY TRAVELER portable communication receiver. The complete receiver with batteries weighs 18 pounds.

Notice the speaker and phone jack on the left side-panel.

The AVC switch is for optional use of the automatic volume control feature. To reduce fading, it should be ON when receiving 'phone signals, OFF when copying code or C.W. signals.

The MAIN TUNING control selects the wanted frequency. The BANDSPREAD TUNING knob controls the bandspread dial and its associated condenser. The BAND SWITCH will permit the selection of the frequency ranges through which the receiver tunes.

In studying about the controls, you should refer to the illustration below.

Compare these controls to those included in other communication receivers you studied.

TUBES EMPLOYED IN S-29

The POWER SWITCH has four positions allowing (1) the receiver to be turned OFF, (2) interconnected for BAT (battery) operation, (3) changed for power line AC-DC operation, or (4) set in position to CHGE (charge) the batteries.

The STAND-BY switch *removes* the current from the plates and filaments of all tubes with the exception of the noise limiter which has a separate filament battery. Since battery type tubes are used, they are ready for operation the moment the filament circuit is completed. The remaining controls are familiar to you.

The tubes are of the 1.4 and 3 volt types.

Battery type tubes are used in the different stages. The filaments are connected in series-parallel to utilize a six volt "A" battery. For power line operation, a type 50Y6-GT tube serves as the rectifier.

Notice the excellent job of shielding the components.

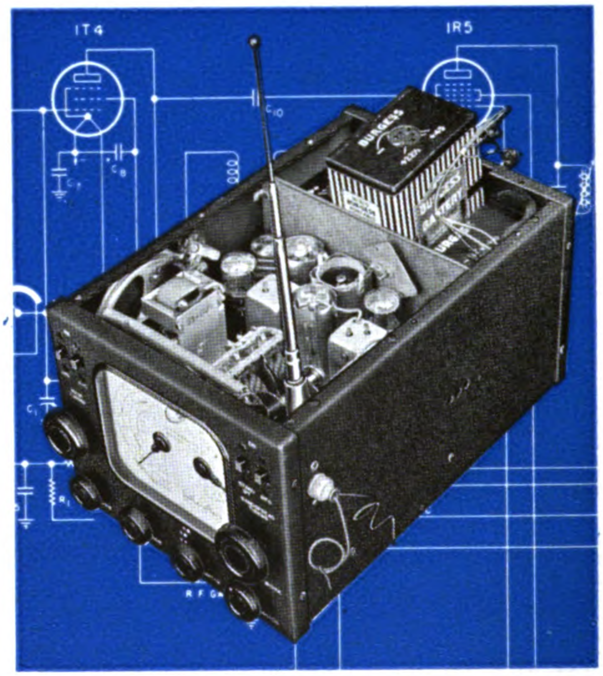


Figure 323. Inside view of the portable S-29 receiver. The illustration shows the telescopic antenna and the socket for connecting an external antenna.

Look up the characteristics of these tubes in the charts of Lesson 9.

There is a radio frequency pre-selector stage using a type 1T4 tube, the pentagrid converter employes a 1R5, the two I.F. stages use 1P5-GT tubes, a 1H5-GT is used as a diode detector and triode audio amplifier, and a type 3Q5-GT serves as the power amplifier. Type 1G4-GT tube is used in the BFO circuit. Another 1G4-GT tube is used as the noise limiter tube. This tube employs a separate 1½ volt dry cell for its filament supply.

A self-contained telescopic antenna is incorporated in the receiver. This antenna may be extended to its full length of 28 inches or compressed entirely into the cabinet. A special socket is provided for connecting to other types of outside antennas.

The battery compartment is visible in the top view illustration. The receiver is very compactly built and has found extensive application.

Phone and CW Transmitter. This compact telegraphy and 'phone transmitter, known as *Hallicrafters* model HT-6, provides for a power input of 25 watts to the final stage. The HT-6 was designed primarily for amateur station use, but served in many commercial and Army applications. For the usual function, crystals and coils for any three bands may be plugged in the sockets provided, pretuned, and then switched as required by a control located on the front panel. This switch properly connects all circuits from the crystal to the antenna.

An electron coupled oscillator unit may be used in place of the crystal. The use of the ECO will permit varying the transmitter frequency in the amateur band employed. Special coils and adapters are also available to convert the transmitter to 10 or 5 meter operation.

Go back to the lesson on oscillators. Compare the circuits of crystal oscillators and the electron coupled type. How can these be altered from one to the other?

Circuit Considerations. A type 6L6 tube is used as the oscillator and for the higher frequencies it also serves as the doubler. Type 807 beam power transmitting tube is employed in the final stage. The audio amplifier needed for modulating the transmitter is made up of a 6SQ7 triode section resistance coupled to a dual triode 6SC7 which serves as an additional voltage amplifier and phase inverter. The audio power amplifier uses a pair of 6L6-G tubes in push-pull.

Make a block diagram of this transmitter. The information presented in this paragraph is sufficient for this purpose.

Two similar power supplies, each using a type 5Z3 rectifier, are included. One serves the R.F. section, while the second supplies plate and filament power to the modulator.

Because the two power supplies are connected as explained, only one of these supplies is employed when telegraphy transmission is used.

Figure 324. A compact 25-watt 'phone and CW transmitter of *Hallicrafters* make.

Each final plate coil is supplied with its own *antenna* coil. Connections to these pickup coils are made by means of flexible leads which may be clipped to the bare winding and include any needed number of turns. When the output coils are adjusted for the particular antenna used with the transmitter, no further adjustment is necessary when changing bands.

In every way, the number of operations to place the transmitter *on the air* is reduced.

A 100-Watt Transmitter. The *Hallicrafters* model HT-9 transmitter rated at 100 watts on CW and 75 watts on 'phone, represents an outstanding engineering achievement in design, compactness, and ease of operation. The needed crystals and exciter coils for five bands may be plugged in the sockets provided and

100 WATT TRANSMITTER HT-9

Having the controls on the front panel is a great convenience in operation.

pretuned. With the exception of the final tank coil which must be changed when shifting to another band, all other functions of band switching, circuit meters, and controls are located on the front panel.

Facts About the Circuit. The exciter unit uses a type 6L6 and a type 6L6 tube in a special circuit. When the transmitter is operated on the crystal frequency, the second 6L6 is the oscillator. When the operation is to be on twice the crystal frequency (doubling), one 6L6 is employed as the oscillator tube and the second 6L6 is the doubler. The switching and socket connections automatically take care of the different sets of coils, crystal circuits, the raising of the bias on the 6L6 for doubling as required, and changing the screen voltage on the 6L6 to give correct excitation.

The modulator must be rated at about 50% of the power delivered to the R.F. stage being modulated. Four 6L6 are capable of producing over 50 watts.

A type 814 transmitting tube is used in the final stage. The modulator employs a 6SJ7, resistance coupled to a 6J5, which is transformer coupled to four type 6L6 tubes in push-pull parallel arrangement.

By using only one hand and wearing shoes with heavy soles, there is little chance of completing the high voltage circuit with your body.

In order to apply plate power in this transmitter, the lid of the cabinet must be closed so as to operate the 110 volt interlocking switch. Such safety switches are usually incorporated in transmitters where the voltages are high enough to be dangerous to human life. High voltage equipment should be serviced and tested with an ohmmeter. For some tests a voltmeter having the correct scale may be connected into a circuit, but your hands should not be in contact with the prods, leads, or meter during the test. Work with one hand while the transmitter is in operating condition. Do not wear headphones while working.

These top connections are made to the plates of the tubes.

It is interesting to note the position of the stages in the top view of the chassis. The modulator is at the left of the chassis, with the four 6L6 tubes in a group. In the back, between the two transformers are three rectifier tubes. In the rear right hand corner is the power supply for the final R.F. tube. Two type 866 rectifiers, with *grid* caps, can be seen. The various coils and crystals (some in cans) are in the center.

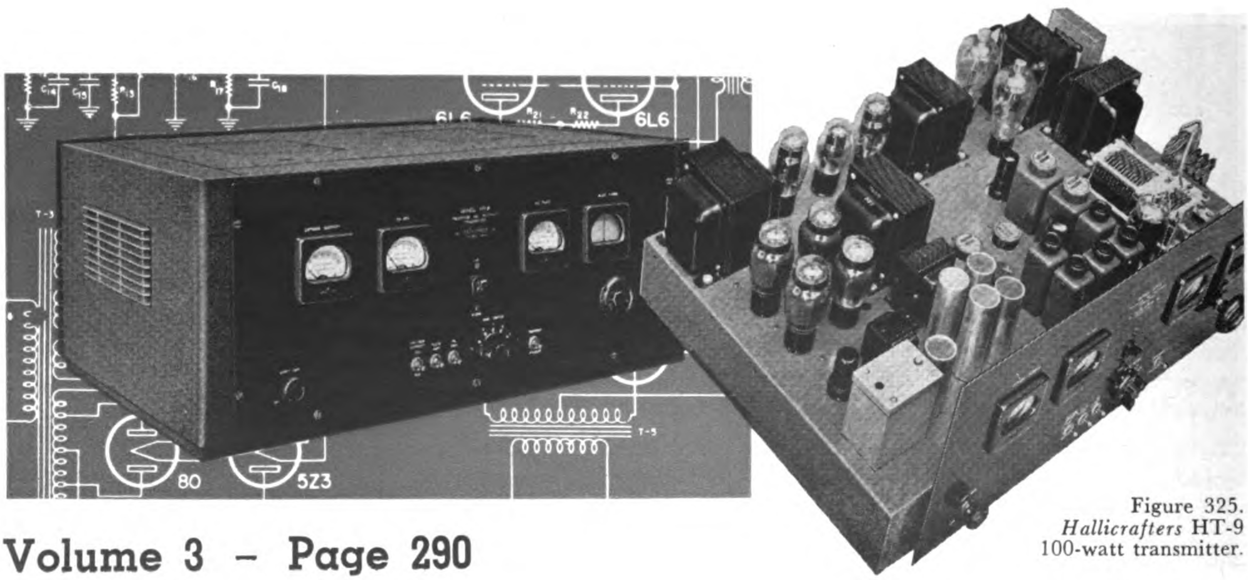


Figure 325. *Hallicrafters* HT-9 100-watt transmitter.

MARINE TRANSMITTER HT-12

Marine Radiotelephone Transmitter. The *Hallicrafter* model HT-12 unit combines a 50 watt 'phone transmitter and a sensitive superhet receiver. The unit is intended for use on small vessels and provides ten crystal controlled transmitting and receiving channels for communications with shore stations, with other ships, and with the Coast Guard.

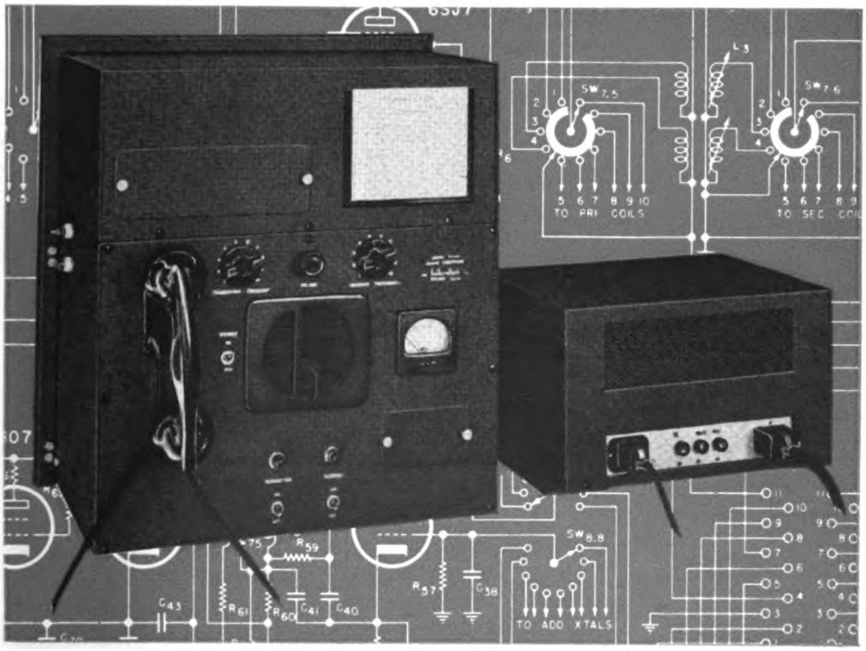
Simplicity of Operation. Selection of the proper operating channel is made by placing the TRANSMITTER FREQUENCY switch-knob in a *numbered* position corresponding to the wanted frequency. The correct adjustments are made beforehand by a technician and the operator need not make any changes. The frequencies used usually lie between 2,000 and 3,000 KC. The receiver and transmitter circuits are interlocked. The receiver volume is adjustable and the loudspeaker included may be employed. While the operator speaks into the microphone, the transmitter remains in operation. Approximately 1½ seconds after the operator has stopped talking, the time lag of the voice control circuit is overcome. This action stops the transmitter operation and the receiver is automatically placed in service.

Because of the simplicity of operation, no special radio license is needed by the operator.

As long as the audio amplifier tube current is varied, and for 1½ seconds thereafter, the relay circuit keeps the transmitter in operation. Without excitation (when talking stops), the plate current is constant and the receiver is connected for operation.

Circuit Considerations. The transmitter uses a 6L6 oscillator which is crystal controlled and may be connected to any one of ten crystal channels. A pair of 807 tubes in parallel are used in the power amplifier. A simple network of resistors is used to prevent parasitic oscillations in the final stage. The modulator consists of a triode section of a 6F8-G, driving four 6L6-G tubes connected in push-pull parallel. Another dual triode 6F8-G is used to control the delay relay.

The receiver employs a 6SK7 R.F. amplifier. A type 6SA7 tube serves as the mixer with a 6SJ7 serving as a separate oscillator. The single stage I.F. amplifier uses a type 6SK7 tube. The diode



The power supply case may be placed in a convenient corner some distance away from the main unit. The radiotelephone may be mounted on a wall or placed on a table.

Figure 326. A marine radiotelephone for ship installation. The unit provides for two way communication on ten separate channels.

CIRCUIT CONSIDERATIONS

Make a block diagram of the receiver.

section of a 6SQ7 tube serves as the second detector. The triode section of this tube and also another triode serve as audio voltage amplifiers. The audio power amplifier tube is a 6K6-G.

The regular power supply employs one 6X5-G and two 5Z3 rectifiers. The 6X5-G serves the receiver.

Power Supply. The radiotelephone is designed for operation from 110 volts A.C. Since most vessels have 32 or 110 volt D.C. supply, a rotary converter is employed to change this source of power to 110 volts A.C. On ships where a 12 volt D.C. supply is available, a heavy duty vibrapack for the receiver and a dynamotor for the transmitter are used.

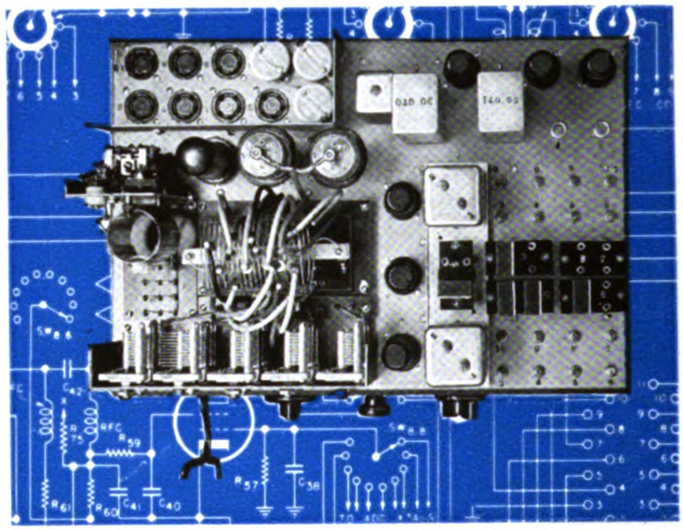


Figure 327. Top chassis view of the *Hallicrafters* model HT-12 transmitter-receiver. Notice the ten sockets for the crystals.

Review Questions and Problems. 1. Could a communication receiver be used as a *home* radio? Are there any advantages to this use? Any limitations?

2. What is the main difference between frequency modulation and amplitude modulation receivers?

3. Why are bands changed, anyway?

3. Why do operators prefer simple methods of band shifting in transmitters? How were the bands changed in the transmitters described Lesson 16?

4. Briefly describe the function of each tube used in model SX-28 receiver. Refer to the circuit shown on page 285.

5. In what way is the action of the "stand-by" switch of the S-29 portable different from the usual communication receiver?

6. How is the HT-12 radiotelephone transmitter changed from transmit to receive positions?

LESSON 26

Radio Compass

PURPOSE OF A RADIO COMPASS. The position of a ship equipped with a radio compass can be determined. The exact location of a nearby radio station (preferably two stations) must be known and a scale map of the waters in which the ship is located must be available. The radio compass will permit the calculation of the distance from the ship to any shore point and will also permit the checking of the regular magnetic compass.

The use of the radio compass is intended for approximately determining the position of a ship in waters near shore.

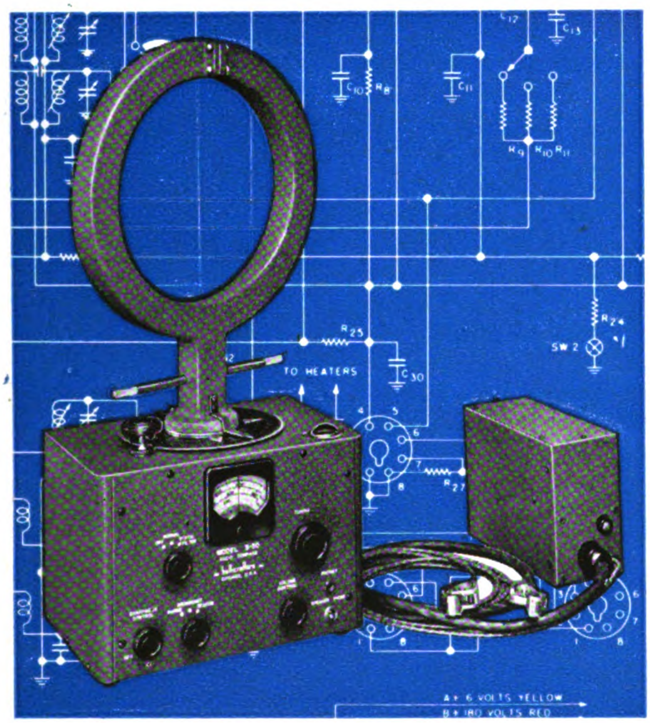


Figure 328. A radio compass receiver and power supply. The use of this radio compass will permit the operator to determine the exact position of the ship on which the compass is installed.

RADIO COMPASS RECEIVER. Essentially, the *Hallicrafters* model S-30 radio compass is a sensitive receiver using a loop antenna. The loop antenna may be rotated and its position (azimuth) is indicated by a pointer on a calibrated dial. The signals from any one station will be maximum when the loop is parallel to or pointing at the station. In using the compass, usually the loop is adjusted for minimum signal or *null* point and is then at right angles to the parallel line to the station. The null or minimum signal point can be detected in the headphones and also on the tuning eye indicator.

If you have a loop antenna portable radio, observe the effects on the operation as the radio is rotated. The variation in volume would be more noticeable if no AVC action were present.

The receiver covers the following frequencies in three ranges:
Beacon Band, 220 to 540 KC.
Broadcast Band, 535 to 1,340 KC.
Marine Band, 1,200 to 3,000 KC.

The unit is supplied with a power supply for operation from a 6 volt storage battery.

Special converters may be obtained.

INSTALLATION SUGGESTIONS. The radio compass should be mounted on a separate bulkhead. The rose of the loop should be well below the eye level and sufficient head room should be available for 360° rotation of the loop itself. In selecting the location for the radio compass remember that it should be as close as possible to the regular compass and chart table. Do not mount the radio compass close to wiring, pipes, or metal objects which would distort the field of the received signal and seriously affect the accuracy of the results.

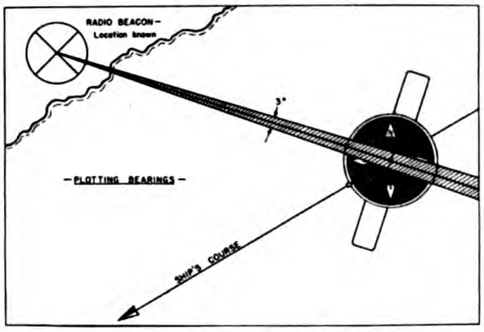


Figure 329. This illustration shows the method for plotting the ship's bearing. The ship is located somewhere within the 3° cone.

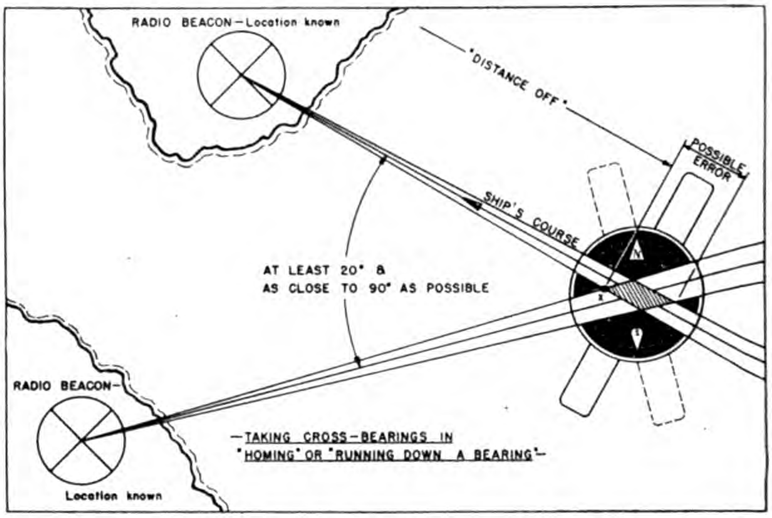


Figure 329-A. A chart showing the method for obtaining the cross-bearing. The possible error area is also shown.

It is possible to find one's position even if only a single known radio station can be received. The bearing is taken at short intervals of time (and distance) apart. The magnetic compass will give your direction of travel during the test period. The angle between the line of the station and the line of travel can be obtained from each of the two bearings. If the distance of travel can be approximated, the new position can be obtained by solving a simple problem in trigonometry.

GETTING YOUR BEARING. There are several ways for finding the ship location, but we will describe the one most often used and which requires the known positions of two radio stations. The positions of the stations are marked on a map you may be using. A bearing is taken for one of the stations and a cone (3° wide) is drawn at the angle indicated by the radio compass in relationship with the magnetic compass. Then a similar bearing is taken for the second station. The intersection of these cones determines the position of the ship.

REVIEW QUESTIONS AND PBOBLEMS. 1. What makes up a radio compass?

2. What accessories are needed to use the radio compass?

3. Obtain an *automobile* map of a single state which includes a part of a large lake or an ocean coast line. Guess the probable location of two or more radio stations. By assuming that you obtain certain readings on a radio compass, locate your ship. Select angle values which will permit the ship to be somewhere in the nearby waters.

LESSON 27

Frequency Standards

WAVEMETERS.* Early frequency standards were simply variable tuned circuits, known as wavemeters. These instruments were calibrated against the output of a rotary high-frequency alternator. The wavemeter is subject to considerable error and, even with present precision manufacturing and calibrating facilities, the *dependable* accuracy is in the neighborhood of only 0.2%.

For majority of applications the frequency produced by R.F. generators must be known to considerable accuracy.

TUNING FORK OSCILLATORS. The first true standards of frequency were electrically excited tuning forks. These forks were maintained in vibration by a regenerative vacuum-tube oscillator circuit and were temperature controlled to provide the highest degree of frequency stability. Frequency was determined by direct reference to the basic element, time, through a synchronous motor-driven clock connected to the output of the oscillator, and comparing the time, as indicated by that clock, with true time as determined by astronomical observatories such as the U. S. Naval Observatory.

Tuning fork oscillators are suitable for producing audio frequencies.

THE USE OF QUARTZ CRYSTALS. Quartz crystals, having a large equivalent inductance and a high Q, possess a degree of frequency stability unattainable with other types of oscillator frequency control.

The essential information on quartz crystals was already presented in the lesson dealing with oscillators.

Frequency standards are divided into two classifications: (1) primary standards of frequency, and (2) secondary standards of frequency. The primary standard, as its name implies, is a fundamental standard against which all other frequency determinations are made. It is an independent standard because it is checked for accuracy and stability by direct measurements against time. The secondary standard has no provisions for checking its frequency directly with time and it must be calibrated by reference to some primary standard.

It is important that you have clearly in mind the difference between primary and secondary frequency standards.

PRIMARY STANDARDS OF FREQUENCY. Fundamentally, a primary standard of frequency consists of a temperature controlled crystal oscillator, a series of multivibrators for subdividing the oscillator frequency, and a synchronous motor-driven clock. The oscillator frequency usually is 50 KC. The crystal temperature is held to within a maximum variation of 0.01 degree Centigrade, in a heated chamber, while the oscillator circuit components are temperature controlled to a lesser degree.

Now is a good time to review the section on multivibrators which begins on page 212, of Volume 2.

The oscillator frequency is subdivided by multivibrators to provide a series of standard frequencies and to obtain a suitable low frequency for driving the synchronous motor clock. Since the time as indicated by the clock is entirely dependent on the frequency of the exciting current, and since the driving frequency is derived from the crystal oscillator, the clock actually serves as a counter for the number of oscillator cycles which occur in a given passage of time. By comparing the clock time with true time, the average frequency of the oscillator can be determined.

The frequency produced may be subdivided down to 60 cycles and a regular commercial electric clock may be used. Clocks are also available for operation from other frequencies.

A primary standard is merely a generator of standard frequencies; to perform actual measurements, additional equipment is required.

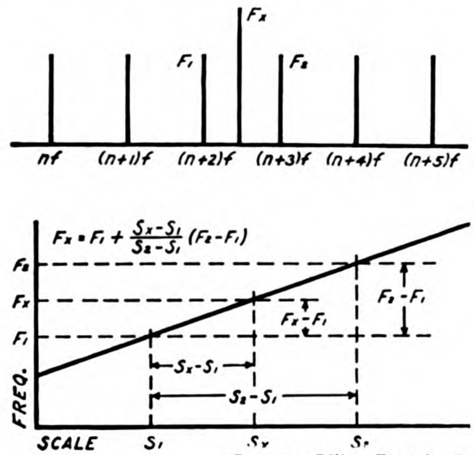
*Much of the material in this lesson is taken from "Frequency Control with Quartz Crystals" published by *Bliley Electric Co.*

A calibrated receiver is, of course, a necessity. For general frequency measurements, the receiver should preferably be the simple regenerative type but superheterodyne receivers can be used. If a superheterodyne receiver is used, extreme care must be taken to make certain that the signal being measured is properly tuned in, as erroneous measurements can easily result from false reception through images, harmonics, or odd beats between the signal and the receiver oscillator. This is most troublesome when the intensity of the signal being measured is quite high.

If the necessary equipment is available, you should carry out the actual measurement of an unknown frequency.

MEASURING TECHNIQUE. The process of measuring a certain radio frequency against a primary standard is, briefly, to locate that frequency with respect to two adjacent harmonics of the standard frequency generator. This is illustrated. Measurements can be made with a fair degree of accuracy by using only the receiver and

This chart is easy to understand by following the explanation in the text.



Courtesy Bliley Electric Co.

Figure 330. A graphical illustration of the method used for determining an unknown frequency with the aid of a frequency standard.

the frequency standard. The signal to be measured indicated as (f_x) is tuned in and the receiver dial setting carefully noted. The output from the primary standard is then connected to the receiver and the dial setting noted for the two harmonics of the standard which are immediately adjacent to this frequency, f_x. The frequency of the two standard harmonics is known from the approximate receiver calibration and, by interpolation, f_x can be determined. A graphical picture and correct formula are stated in the figure.

The same general process can be followed by beating a calibrated oscillator against f_x, and the two adjacent standard frequencies, in the receiver. The interpolation is then carried out from dial settings of the oscillator corresponding to f_1, f_2 and f_x. This latter method is advantageous where the signal strength of f_x is very low or where it is varying widely due to such effects as fading.

The *Hallicrafters* HT-7 frequency standard (illustrated) consists of a stable crystal oscillator providing either 1,000 KC. or 100 KC. output, together with a 10 KC. multivibrator and a harmonic amplifier.

SECONDARY STANDARDS OF FREQUENCY. Any previously calibrated frequency determining instrument is a secondary standard of frequency. Through common usage, however, secondary standards are considered to be crystal controlled oscillators of high stability employed for frequency measurements.

Secondary standards are used where the extreme precision and flexibility of the primary standard is not required and more simplified equipment is adequate. They have no provision for directly determining frequency and must be both calibrated and checked against some primary standard.

LESSON 28

Frequency Meters

Purpose of Frequency Meters. Direct reading frequency meters are used to indicate the frequency of the alternating current produced by power generators. The frequency generated by an audio frequency signal generator or obtained from some other source can be measured and read directly on an electronic frequency meter. Such a meter may be used also as an indicating instrument in testing quartz crystals by a comparison method or experimentally as the base of an FM modulation indicator. Combined with a photo-cell and amplifier, it can be used as a speed indicator.

Vibrating Reed Frequency Meter. Meters of this type are used to indicate the frequency of A.C. power and are used on engine-generator sets, in telephone work, and on panel and control boards in central stations and industrial plants. The speed of A.C. generators must be adjusted to produce the required frequency — usually 60 cycles per second.

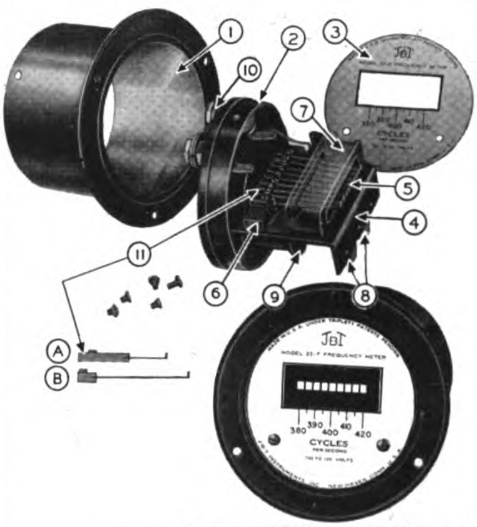
As shown in the illustration, a meter of this type consists of a case (1), base (2), dial (3), central mounting frame (4), a series of spring steel reeds (5), screwed to a reed mounting bar (6), an individual driving coil (7) surrounding each bank of reeds, a permanent magnet (8), a series resistor (9), and terminal studs (10). In operation, the alternating current (or interrupted direct current) excites the driving coil. Each reed is adjusted to respond by mechanical resonance to a single frequency only, and the one reed *in tune* with the frequency in the coils will respond. This reed will vibrate rapidly because of polarization by the permanent magnet and the induced magnetism from the coil. A series resistor of a suitable size adapts the instrument to the operating voltage. The frequency of the current can be read opposite the vibrating reed on the graduated face of the instrument.

Usually these instruments are supplied for indicating frequencies around 50 or 60 cycles. If the frequency of the source is fractional — for example, 60.5 cycles per second — the 60 cycle reed will vibrate to about half its full amplitude and the 61 cycle reed will vibrate similarly.

Direct Reading Electronic Frequency Meter. It is possible to measure the frequency of the exciting voltage with the aid of electronic circuits. The unit illustrated can be used to measure zero to 50,000 cycles per second, in six ranges for greater accuracy. The frequency may be read on a calibrated meter or the unit may be used to drive a recorder. Variations of the signal voltage between ½ and 200 volts will not upset the 2% accuracy of the instrument. The unit may be operated from 60 cycle A.C. with voltage variations between 105 and 125 volts. Built-in electronic regulators compensate for these changes. The circuit of this unit cannot be released at this time because of War conditions.

The circuit employed converts frequency supplied to the input to corresponding D.C. current which is used to operate the calibrated meter. A sensitive relay is included to protect the meter from overload in case higher frequency than the maximum of the range used is applied to the input.

Portable Army radio equipment is often used with A.C. generators driven by gasoline engines. The speed of the rotation is adjusted to produce current of the required frequency.



Courtesy J-B-T Instruments, Inc.

Figure 331. An illustration of a complete vibrating reed frequency meter and the components which make up the unit. The components are explained in the text.

All reeds of a frequency close to the frequency of the source, will vibrate to some degree; the strongest vibration will be present in the reeds closest in frequency.

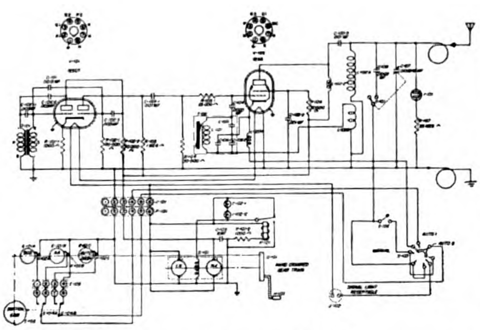
Courtesy North American Philips Co.

Figure 332. A direct reading frequency meter which employs electronic circuits.

LESSON 29

Courtesy Bendix Aviation, Ltd.

Figure 333. The emergency transmitter in operating position. Notice the antenna reel and the method used for securing the antenna wire to the equipment.



Circuit of the *Gibson Girl* emergency transmitter.

Automatic Emergency Transmitter

General Description and Purpose. The *Gibson Girl** emergency transmitter is designed for operation from a rubber life raft. The transmitter is self-contained in a sturdy metal case which is molded to the contour of the operator's legs, between which it is held for operation. The equipment includes a reel, holding 300 feet of antenna wire, in a compartment in the front panel of the transmitter. A kite which is easily assembled is provided also. This kite will lift the antenna wire and should be used when wind velocities are between 7 and 40 miles per hour. A balloon which is inflated from a hydrogen generator is employed if there is lack of wind.

The set provides automatic code transmission of predetermined signals so that any operator, no matter how untrained, can send constantly repeated distress signals which, when received by rescue parties, permit bearings to be taken. The transmitter operates on the international distress frequency of 500 KC. with 1,000 cycle tone modulation. At sea, the signals produced will blanket an area of at least 200 mile radius.

How the Transmitter Is Operated. All the equipment of the emergency transmitting system is packed in a bag attached to a parachute. The transmitter is water tight and, since the packed bag will float, the equipment may be dropped to survivors in distress or at the time a plane is being abandoned.

The operating controls of the transmitter are grouped in the elongated-oval protective depression on the front panel. Radium-illuminated markings enable the controls to be operated at night. All electrical power is supplied by a hand-driven generator, operated by a crank. The proper speed is indicated by the lighting of an indicator lamp, and the voltage output is made constant over a wide range by the use of relay-type voltage regulator. The hand crank also rotates the keying apparatus. The accuracy of the keying mechanism speed is maintained by the use of a slipping clutch and governor arrangement.

A selector switch on the front panel of the transmitter allows selection of (1) automatic radio keying, (2) manual radio keying, (3) manual signal lamp *keying* for night signalling, or (4) continuous signal lamp light.

Circuit Employed. The transmitter uses a type 12SC7 dual triode tube as the audio oscillator and audio amplifier. A type 12A6 tube is used as the electron-coupled R.F. oscillator and is modulated with the audio tone. The keying circuit is in the cathode return of the R.F. oscillator tube. The antenna is resonated by a tuning control mounted on the front panel. Maximum radiation efficiency is indicated by maximum brilliance of the indicator lamp provided for this purpose. Plate-loading characteristics and antenna height have almost no effect on the frequency.

*Called the *Gibson Girl* because of the hourglass shape of the transmitter. This equipment is manufactured by *Bendix Aviation, Ltd.*, subsidiary of *Bendix Aviation Corp.*, through whose courtesy the material for this lesson was obtained.

LESSON 30

High Frequency Heating

Basic Principles. Energy cannot be created or destroyed, but it can be changed in form. The changing of the form of energy is essential for its economical transmission or for proper application. Many industrial problems can be overcome by applying heat to substances with the aid of high frequency generators. Heat can be induced in metallic and non-metallic materials from an associated radio transmitter. Proper coupling must be made for magnetic or dielectric transmission of energy from the high frequency generator to the substance to be heated. The generator must be easily controlled, but the exact frequency produced and slight drift are not important and simple self-rectifying self-excited oscillators are used. The main advantages of high frequency heating lie in uniform distribution of heat within the substance and the relative coolness of the nearby surroundings.

Generating Equipment. The high frequency oscillators used to generate the power needed are available commercially in sizes from a few watts to about 600 kilowatts. The basic circuit of the generator is shown in the diagram. You will notice that this is a push-pull self-excited oscillator circuit with separate rectifiers to convert the stepped-up high voltage 60 cycle A.C. to D.C. This circuit shows the main elements and is not to be considered as complete.

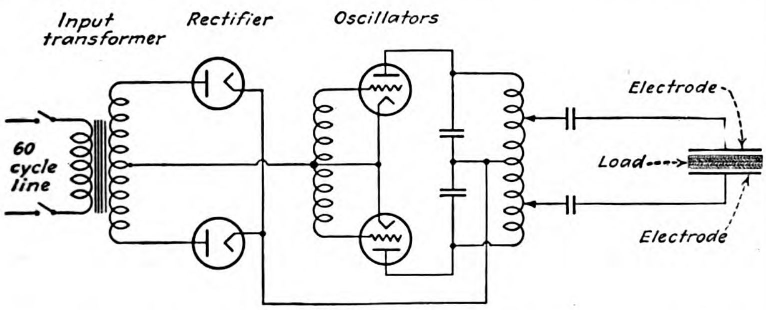


Figure 335. The basic circuit of an electronic R.F. generator suitable for producing the power needed for high frequency heating.
Reprinted through the courtesy of "Chemical & Metallurgical Engineering" and The Girdler Corp.

The values of the inductance and capacity are selected to give the proper frequency for the application at hand. Correction may be incorporated in the design for the effects of the load. The circuit shows the dielectric method for applying energy to non-metallic materials. Specially shaped coils, or perhaps the actual inductance of the unit, are used for delivering the energy to metallic substances.

Since the output high frequency wave-form and stability are not important in applying high frequency heating, some commercial generators use spark-gap oscillators.

For heating dielectrics (non-metallic substances) there is considerable advantage in using very high frequencies. Higher frequencies usually produce lower voltages across a given space of the dielectric and permit greater concentration of power. However, the efficiency of the generating equipment falls off as the frequency is increased and the actual choice of the operating frequency is a compromise. Practical experience has shown that frequencies in the five to fifteen megacycle range can be generated economically for

Photograph courtesy of RCA

Figure 334. To attach together sheet thermoplastics and thermoplastic coated fabrics, RCA has developed the electronic "sewing" machine. This modern machine uses high frequency heat to solve another industrial problem.

The hardening and annealing of steel, drying of glue in ply-wood, and setting of certain plastics are a few industrial applications.

Less power output is obtained from the same transmitter as the frequency is increased.

You can read more about *heat* in any elementary book on Physics.

such applications. Units built for producing heat in metallic objects are operated in the 100 to 300 KC. range.

PHYSICS OF HEAT. Heat energy is measured in B.T.U.'s. Electrical energy is measured in watts, or in kilowatts, per period of time. One kilowatt hour (1,000 watts applied for one hour) is equal to 3,413 B.T.U.'s. In order to determine the requirements for high frequency heating, it is necessary to know the weight, specific heat* of the substance, and the temperature rise needed. With this information it is possible to calculate the B.T.U.'s required for the task, and by converting this to kilowatts understand how large a high frequency generator will be needed. Efficiency of 50% may be assumed, and this means that the equipment needed must be rated at twice the calculated power requirements.

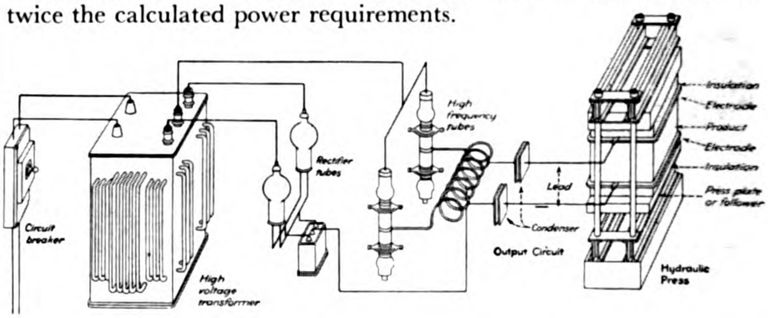


Figure 336. A pictorial view of the essential components which make up a high frequency generator used for drying ply-wood.

Reprinted from "Aviation" with permission of The Girdler Corp., Thermex Division

APPLICATION TO NON-METALLIC SUBSTANCES. Most often the object of using high frequency heating of non-metallic materials is to (1) heat materials uniformly and at a rapid rate or (2) to bring about chemical reactions. Practically all non-metallic items can be rapidly and uniformly heated with high frequencies. During Wartime, high frequency heating is especially important in speeding the production of ply-wood which is used for certain types of boats and airplanes. High frequency dielectric heating can be applied to reduce the drying time of paper, textiles, powders, ceramics, and tobacco. This type of heating is essential in the manufacture of certain type of plastics. Thick sections of rubber can be speedily cured, or rapidly softened for masticating purposes with high frequency heating. The heat generated with the aid of high frequency equipment can be used to destroy infestation in grain and cereal without harming the products.

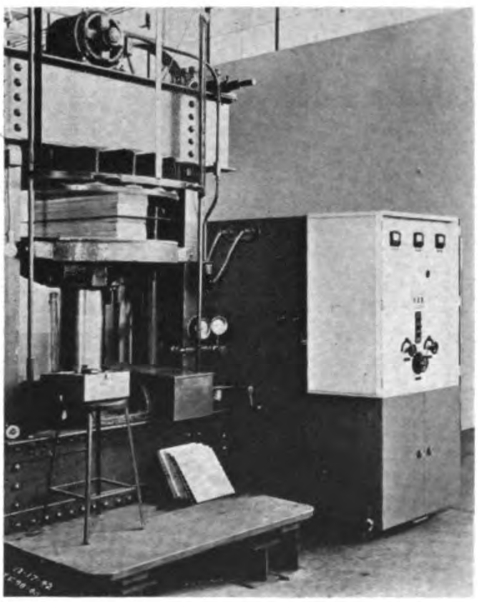


Figure 337. A view of a press and a high frequency generator which is manufactured by *The Girdler Corporation*. The photograph shows high frequency heat being used to cure glue joints in two 4½ inch wood blocks.

APPLICATION TO METALLIC SUBSTANCES. High frequency heating has been applied to ferrous and non-ferrous metals for hardening, annealing, melting, brazing, soldering, bombarding, and coating. The section of the metal object to be heated is placed within copper tubing, made in the form of a coil large enough to surround the section under treatment. The heat energy is induced only in the area lying within the turns of the *work coil* (as this inductance is called), and the effect is so instantaneous that it is a relatively simple matter to apply the coil or connected coils to one section or single part, or simultaneously to two or more sections and to heat those sections in a manner that will produce no distortion or structural changes in other sections of the heated part. By connecting a group of suitable coils in series, many similar items can be treated at one time, thereby speeding up production.

*Specific heat is the number of B.T.U.'s required to raise one pound of a material 1 degree F. Water is used as a standard and is assigned the specific heat of 1. That is, it requires 1 B.T.U. to raise 1 pound of water 1 degree F. (at about 64° F.). For example, most wood products at normal moisture content have an average specific heat of .45.

LESSON 31

Electronic Shaping Circuits

PURPOSE OF SHAPING CIRCUITS. Electronic shaping circuits change the shape of current and voltage waves with the aid of vacuum tubes. For example, the appearance of a sine wave before and after shaping is shown below. These circuits and their effects are essential in television and radar work, and are also used in many industrial electronic devices. In television work for example, these circuits are used in blanking and synchronizing.

You already have learned that radio circuits are a combination of resistors, coils, condensers, and vacuum tubes. This is true, also, of course, for electronic shaping circuits. Therefore, since you have a thorough understanding of the action of these basic units, you need only find out how these components behave in combination with each other to form various shaping circuits.

This lesson was prepared by L. M. Feiler, a well known radio engineer, at present doing design work on Radar equipment.

Only the very simplest shaping circuits are discussed in this lesson.

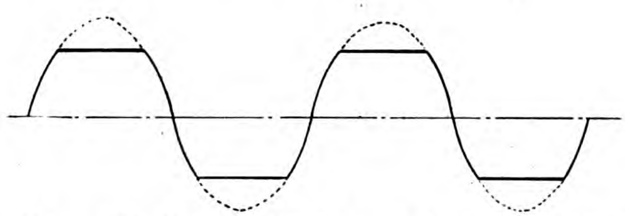
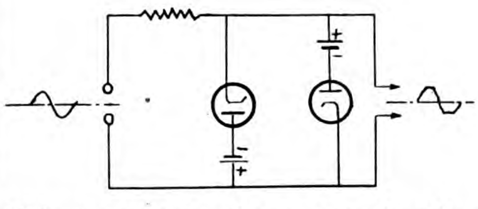


Figure 338. A graph of a sine wave showing the effect of clipping the upper and lower peaks.

Please understand that there are changes, but no abrupt changes in a sine wave.

CLIPPER CIRCUITS. Usually, clippers are used in forming square waves out of sine waves which, in turn, are produced with a regular oscillator. The result of this process was illustrated above. Recall the explanation of a sine wave as given on page 55, Volume I. The sine wave may start at a minimum value of intensity, rise smoothly to a maximum in one direction, fall back to a minimum, then the polarity is reversed and the action is repeated. Examine the drawing of a sine wave. Notice that the maximum and minimum values occur at single specified instants of time. The entire variation is smooth — there are no abrupt changes or discontinuities.

We can change the shape of this sine wave by cutting off the extreme top and bottom parts. With this change, the maximum and minimum values will no longer occur at a single instant of time, but will now occur over a longer period of time. The wave is no longer smooth — abrupt changes in values have been introduced, and we call this new type of wave a modified *square wave*. The square wave has important electronic applications because many shaping circuits depend for their operation on abrupt changes which are present in the square wave.

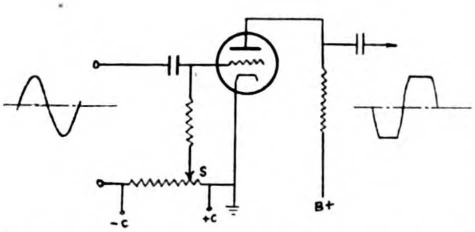


This is a basic clipper circuit using two diodes. In commercial circuits no separate batteries are used, but the circuit is so arranged that the correct polarities are obtained from a single power supply.

If you connect a triode vacuum tube as shown in the figure, and apply suitable plate voltage, grid bias, and a high-amplitude sine wave signal, the plate current will vary as shown. The signal voltage applied to the grid should be great enough to cause the plate current to drop to zero for a short portion of the negative part of

CLIPPER CIRCUIT

Notice that the triode clipper circuit, besides clipping the peaks of the sine wave, behaves very much as a triode tube amplifier increasing the signal and reversing the phase.



The results shown in Figure 339, were obtained from this type of circuit.

the cycle as shown at the zero current point, *a*. We have now *clipped* the negative crest of the sine wave. Before the positive maximum value of the sine wave is reached, the grid causes the plate

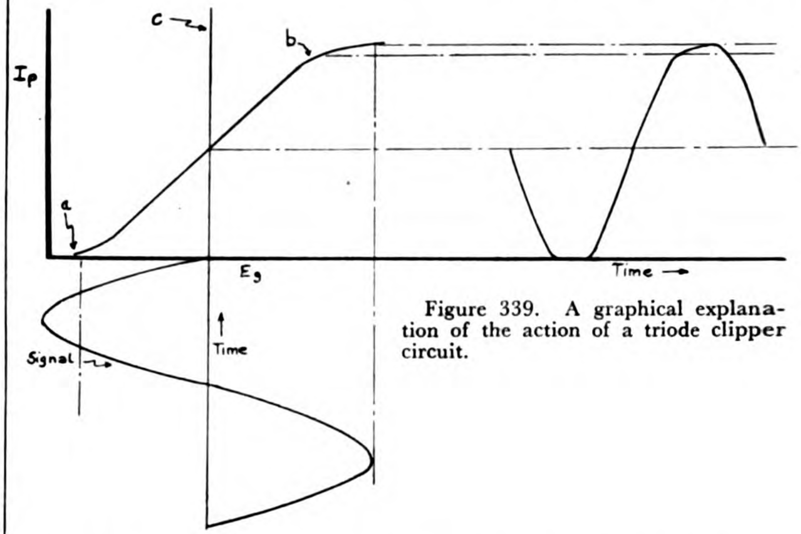
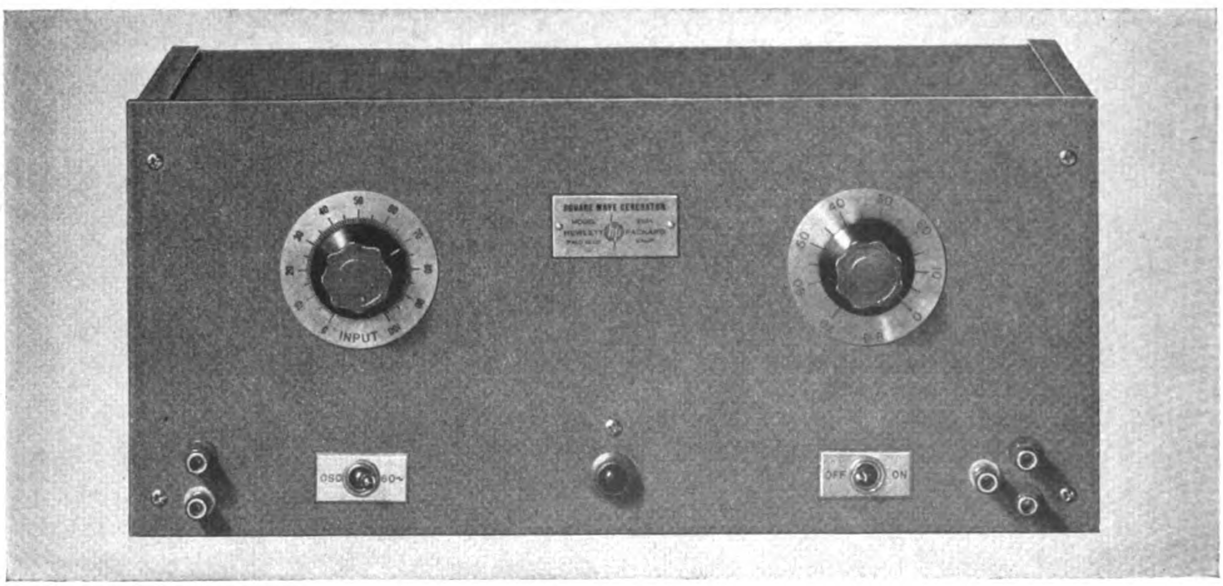


Figure 339. A graphical explanation of the action of a triode clipper circuit.

current to reach saturation value, as shown at *b*. The plate current can no longer rise rapidly and, therefore, remains at a relatively constant value for a period of time. The shaping of *one* cycle of the sine wave is completed by this clipping off of the positive crest.

You understand, of course, that by varying the position of the slider S in the figure, we can shift the operating line *c*, either to the left or to the right. If shifted a certain amount to the left, only the bottom or negative half will be clipped. If shifted to the right, only the positive side will be clipped.



Courtesy Hewlett-Packard Co.

Figure 340. Special signal generators are available for producing square waves. Some units are designed for operation in conjunction with a sine wave audio frequency generator, and convert such sine waves to square waves of the same frequency.

The triode tube clipper circuit may be replaced with a circuit using either a diode or a pentode. A diode clipper circuit is also illustrated.

DIFFERENTIATOR, INTEGRATOR

DIFFERENTIATOR CIRCUIT. The differentiator is a circuit producing a voltage or current proportional to the *speed* with which the applied wave changes in value. This circuit is used primarily to obtain narrow pulses (pulses of very short time duration) from broad pulses.

When a sudden change occurs in the voltage across a condenser C, and a resistor R, connected in series, most of the voltage drop will appear across the resistor. This is due to the fact that the current through the condenser is proportional to the speed of change of the applied voltage. Since the applied voltage has changed suddenly its *speed* of change is high. The voltage drop across R is equal to the current multiplied by the resistance. The resistor is of a fixed value and, if the current is high, there will be a large voltage drop across this resistor. However, the total voltage drop in a circuit can never exceed the voltage applied; therefore, the drop across the resistor is nearly equal to the applied voltage. A sudden change in applied voltage is represented by *a* in the figure, and the resulting voltage drop across R, is represented by *b*.

At point *d,* the voltage is not changing although its value is high. This is an important distinction. The *value* of a voltage at any time need not be related to its speed of *change* at that time. Since the speed of change at *d,* is less than at *a,* the current in the circuit, during the time interval represented by *d,* is less also. If the current is decreased, the voltage across the resistor is decreased and, therefore, the voltage is shown as decreasing at *e*. At each sudden rise and fall of applied voltage, a sharper rise and fall of resulting voltage across the resistor occurs. The resulting voltage variation across the resistor is called a differentiated wave.

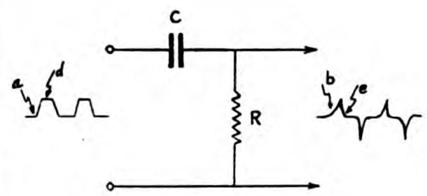
Speed is used in the sense of the rate of change.

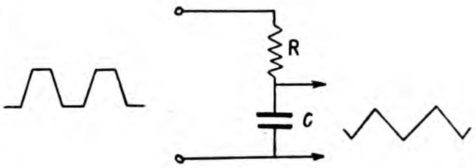
A sudden change from one value to another represents a high rate of change since no time duration was involved to accomplish this change.

INTEGRATOR CIRCUIT. The purpose of the integrator circuit is to smooth out or delay any sudden change in voltage or current. Both in its action and in its inter-connection of parts the integrator is essentially the differentiator circuit in reverse. It depends for its operation on the fact that the voltage drop across a condenser lags behind the current flowing through it. If we change the applied voltage suddenly, across the circuit illustrated, as when we apply a square wave of voltage, the *current* will rise suddenly, but the *voltage* across the condenser will change slowly. Please notice that the voltage across the resistor will still rise as explained for the differentiator, but this time you are not interested in the voltage across the resistor—the output is obtained across the capacitor. The speed with which the voltage rises across the condenser depends on the value of C and R. The larger their values, the more gradual is the voltage change.

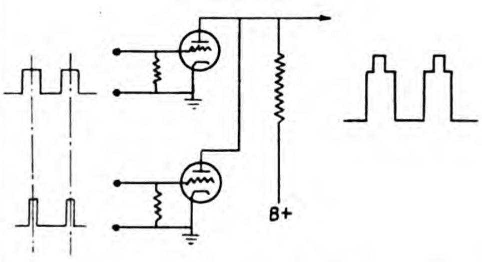
Various forms of integrator circuits combined with special gas discharge tubes are used in generating the sweep voltages of cathode ray oscillographs.

MIXER CIRCUIT. Quite often in changing the shape of a current or voltage wave, it is necessary to combine the effects of clippers, differentiators, and/or integrators. A mixer circuit is used for this purpose. It is generally made up of two tubes or two sections of a dual tube. Different signals are applied to the grids of each tube, and since their plates are connected together, the signals are electronically combined to form a new wave shape.



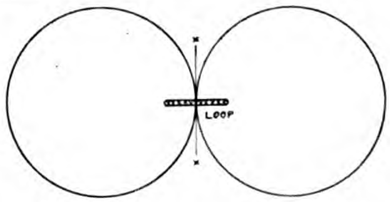


A basic differentiator circuit is shown above; an integrator circuit is below it. At the bottom of this column is a basic mixer circuit.

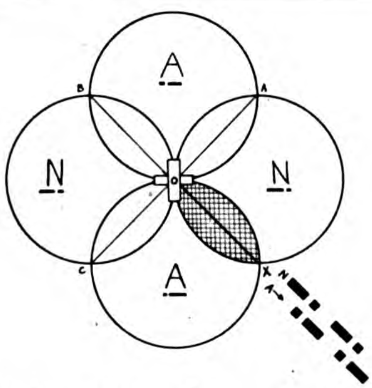


LESSON 32

A review of Lesson 26, dealing with the radio compass, will help you in understanding this material.



Radiation pattern from a compact loop antenna. To fix the idea in your mind, stand a coin on its edge directly above the view of the loop. Assume the coin is the loop antenna. If the page of the book is held flat, the figure-eight radiation extends away from all edges of the coin; in the directions shown and also to the top, bottom, and at all angles.



Radiation pattern from a beacon station. You must understand that either the code of letter *A* or letter *N* predominates in various areas, but these are of equal intensity along the lines marked OX, OA, OB, and OC.

Aircraft Direction Finders and Beacons

Need for Guidance in Flight. In order to travel between two points, sign posts, a trail, or familiarity with the terrain is essential. These factors are not present in flight, and the science of *avigation* depends on radio equipment to supply artificially these signs and directions. The road is created for the pilot by using the radio range or beacon system. Even with a road to travel, confusion can exist unless there is a means for identifying the passing localities. Radio *markers* are indicated on maps used by pilots and are found with radio equipment. Further, by using a direction finder, a pilot can take his bearing and determine his location. This is a great aid in taking detours out of storm areas, checking progress toward the destination, or being able to return to the range (beacon) after leaving it for some reason. Radio equipment is also used to determine the height of the plane above ground and for landing under adverse conditions.

Radio Beacon System. A loop antenna has highly directional characteristics. The radiation is in the form of figure eight, with each circular lobe extending in the opposite direction and in the direction of a line drawn through two opposite sides of the loop (see the figure). If two such loop antennas are placed very close together but at right angles, the field strength pattern illustrated results. In the line marked OX, single lobes of each loop antenna deliver equal signal. There are four such lines to any one radiating system of this type; lines OA, OB, and OC. If one loop antenna is connected to a transmitter which automatically sends letter A (- — in code), while the second antenna serves a transmitter which send out letter N (— - in code), one or the other code letter will be heard if the plane is in the area predominantly under the influence of *one* lobe only. The code letters A and N are synchronized, so that the dot of one letter fits into the space between the dot and dash of the letter from the second loop. The dash of each N occurs during the time the blank space is present at the end of one A and beginning of another A. And similarly, for the dash of each A.

You can readily see that if a pilot is flying on the course (line OX) he will receive the letter A and N equally well, these will *fit* together, and no aural response will be received. But if the plane deviate from the beacon, either the letter A or the letter N will be heard, and this will tell the pilot in which direction he has moved off the range. The intensity of the aural signal suggests the distance off the beacon path.

The radio beacon system in the United States operates on frequencies in the range from 200 to 400 KC. The stations are spaced at distances of about 200 miles. The A and N signals are sent for about 30 seconds, then there is an interruption followed by a code signal sent first from the N loop, then from the A loop. The code signal is used to identify the station being received. By referring to a map, the pilot knows what station is serving him and at what point to tune in the next beacon station in his line of travel.

LESSON 33

Automatic Radio Direction Finder

DIRECTION FINDERS. The radio compass discussed in an earlier lesson can be made to serve as an aircraft direction finder. A direction finder of a similar type may be used with an automatic steering device to head the plane toward the location of a selected station, without attention from the pilot.

The *Sperry Gyroscope Co.* has developed a radio direction finder designed specifically for the needs of air transport service. This automatic radio direction finder will function with the minimum of attention and incorporates a number of additional desirable features. This unit* will be described in this lesson.

GENERAL DESCRIPTION AND PURPOSE. The *Sperry* automatic direction finder supplies continuous and automatic non-ambiguous bearing indication and simultaneous headphone reception in the 200 to 500 KC. and 550 to 1,500 KC. bands. Its visual indications are given on a horizontal dial, and bearings can be easily obtained.

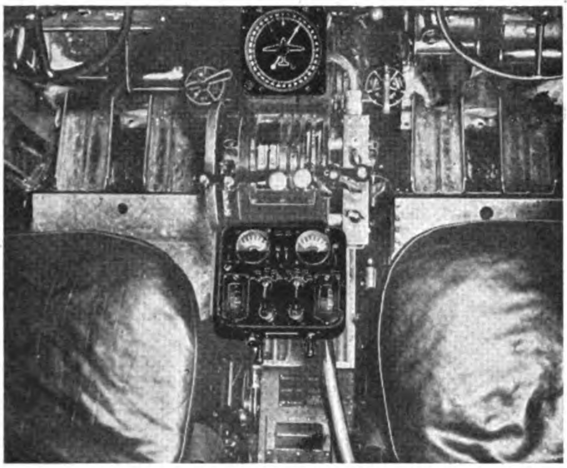
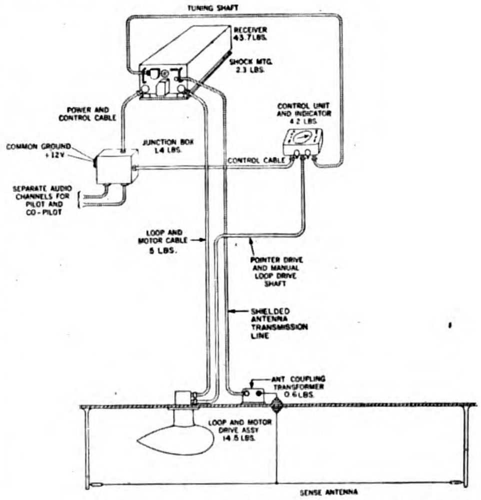


Figure 341. Dual control type, automatic direction finder installed aboard a transport plane. The dual control unit besides automatically supplying the direction of a radio station ahead in the path of travel, also permits the pilot and the co-pilot to determine their exact position by taking cross-bearing of two known radio stations.

The equipment consists of a control and indicating unit, a sense antenna, receiver, and a streamlined housing in which is mounted a pair of loops. The bearings are indicated by a pointer moving over a 360° scale. This pointer is connected by a flexible shaft to the loop assembly which is fitted with a motor controlled by the receiver output. The action of the motor control circuits brings the loop to a null on the station to which the receiver is tuned, and this null position is continuously and automatically maintained. When precipitation static conditions are encountered, the sense antenna is disconnected and a second shielded loop substituted for

*The contents of this lesson were taken from a booklet describing "The Sperry Automatic Radio Direction-Finder" issued by the *Sperry Gyroscope Co., Inc.*

The sense antenna shown in the drawing below permits the determination of a non-ambiguous direction. Loop antennas alone indicate the line of direction only.



Courtesy Sperry Gyroscope Co.

This drawing shows the inter-connection and weights of the components which make up the automatic radio direction finder.

it by means of a switch. Automatic operation is provided as before, except that a line of bearing is given instead of the single-direction non-ambiguous bearing furnished with the sense antenna connected.

The wanted radio station must be tuned in manually.

CONTROL UNIT AND INDICATOR. All the controls, indications and navigation scales of the equipment are combined in a single location. The azimuth indicating pointer on the control dial has a maximum speed of 30 degrees per second in turning to the desired stations, and comes to rest on the correct bearing without overshoot or hunting. Flexible shafts carry the tuning drive from the control unit to the receiver and the pointer drive from the loop assembly to the control unit (see the arrangement drawing). The drive shaft from the loop to the pointer serves a dual function: in automatic direction finder operation this shaft is driven by the loop-motor, but during manual aural-null tuning, the loop is rotated through this same shaft with the aid of the tuning cranks on the control unit.

Refer to the drawing on the previous page.

Figure 342. The control and indicating unit of a *Sperry Gyroscope Co.* automatic radio direction finder, single control type.

In addition to this arrangement for manual orientation, the loop-motor switch provides a motor drive for rapid right or left rotation of the loop.

RECEIVER AND POWER SUPPLY. The radio receiver used with this direction finding equipment has been especially designed. Required sensitivity, selectivity, and image rejection have been incorporated. The selectivity is such that bearings can be taken on range stations separated by only 3 KC., with audio fidelity adequate for intelligibility. This receiver and power supply are in one unit. The equipment is available for 12 or 24 volts D.C. operation — power at one of these voltages is usually available in commercial aircraft.

The same receiver serves for audio reception.

ADVANTAGES OF THE AUTOMATIC DIRECTION FINDER. The direction finder may replace the range receiver in many installations. Under these conditions, the auxiliary receiver would normally be used as a range receiver, with the automatic direction finder continuously in use as a homing or drift indicator when tuned to the range station next ahead.

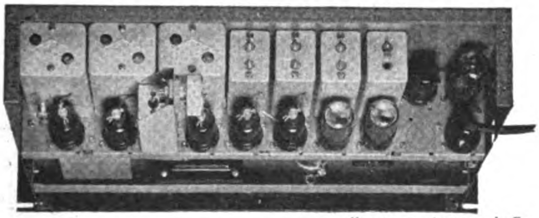
The greatest advantage of the automatic direction finder, of course, lies in the fact that once tuned to a station it continues to indicate the direction of that station. On the other hand, the loop of a manually operated radio compass must be manually adjusted for the null position to take a bearing. The automatic radio direction finder checks the cone of silence (area over the station being received) unmistakably, the pointer swinging around 180° and pointing in the opposite direction in the time it takes for the airplane to cross the cone of silence.

The motor driving the loops is automatically operated from a circuit controlled by the signal strength of the incoming signals.

LESSON 34

Aircraft Altimeter

The fact that a radio wave can be reflected just as light and sound waves, has been known for a long period of time and this phenomenon used, for example, to measure the height of the ionosphere. As early as 1922, the Navy had scientists studying the reflection of radio waves from tall buildings. Independent workers in 1930, using short wave transmitters, succeeded in obtaining noticeable reflection from an object as small as an airplane. In 1932, Bell Laboratory engineers observed that a plane flying at 1,500 feet produced a "flutter" of about 4 cycles per second in the indicating instruments. In the same year, under favorable circumstances, Navy technicians were able to detect a plane at distances as great as 50 miles, but the results were not dependable.



Courtesy National Co.

Figure 343. You will find sections of special electronic equipment very similar to radio receivers. The illustration shows the R.F. and I.F. portion of a communication receiver.

In 1938, *Western Electric* developed the *absolute altimeter,* an instrument which indicates the exact height of a flying plane above the ground directly below, and not the height above sea level.

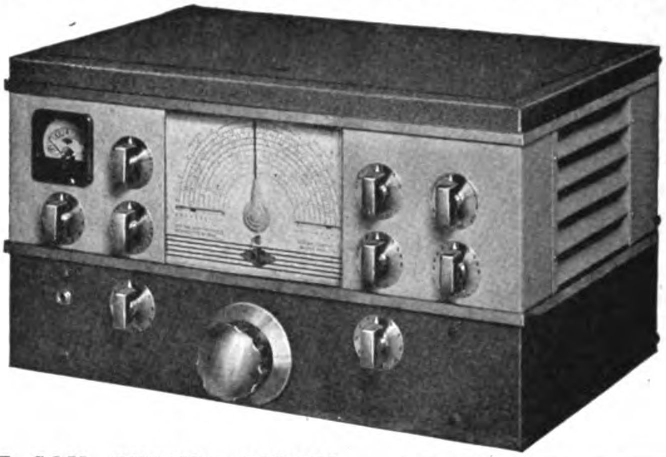
Absolute Altimeter. In its basic form, the absolute altimeter may consist of a short-wave transmitter and a sensitive special receiver. A special keying unit incorporated in the transmitter controls the operation and permits the sending of short pulses (a few microseconds in duration) several times per second. This pulse of radio energy is radiated from a directional antenna towards the ground below the plane. Although the receiving antenna is also *facing* the earth below and is separated from the transmitting antenna, a certain amount of energy of this transmitted pulse is impressed upon the receiver. The radio wave transmitted, upon striking the earth, is reflected upwards and picked up by the receiving antenna. The receiver *considers* the time element involved in the passing of the wave from the airplane to the earth directly below and back to the plane. Since the speed of the radio wave is known (186,000 miles per second) and the time of passage is known, the distance traveled may be obtained. The height of the airplane is actually half this distance. This fact is easy to see if you will bear in mind that the time considered represents the passage of the radio wave from the airplane to the ground and back to the plane.

A somewhat different principle is used in modern type altimeters, but this information is of a secret nature at present. The description presented will give you the essential facts.

The receiver evaluates this time difference in terms of a voltage which is used to operate a meter calibrated in feet.

WHAT MAKES A FINE RECEIVER?

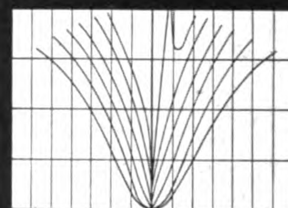
THE NATIONAL NC—200 COMMUNICATION RECEIVER



MOVABLE COIL TUNING SYSTEM—In the NC-200 Communication Receiver, R.F. and Oscillator coils, together with their padding condensers, are completely inclosed in separate pockets in a heavy cast-aluminum shield. This shield moves bodily on a track, bringing the desired coils into operating position directly below the tubes and condenser, thus providing the shortest possible leads. Unused coils are removed out of the way.

MOVABLE COIL TUNING UNIT

WIDE RANGE CRYSTAL FILTER—The wide range crystal filter of the NC-200 has selectivity adjustable in six steps, corresponding to total bandwidths from 200 cycles to 7,600 cycles. The phasing circuit provides rejection ratios as high as 10,000 to 1, when the interfering signal is only a few hundred cycles from the desired signal.



WIDE RANGE CRYSTAL FILTER

TEN CALIBRATED COIL RANGES—Six coil ranges provide continuous coverage from 490 KC. to 30 MC. The remaining ranges cover four amateur bands, each band being spread out over the major portion of the dial scale.

10 CALIBRATED COIL RANGES

PORTABLE OR A.C. OPERATION—The NC-200 has a complete AC-operated power supply built in. For emergency or portable use, all that is necessary is to plug in a battery cable in place of the dummy plug at the back of the receiver. This makes all necessary connections, and leaves the speaker and stand-by switch in operation.

PORTABLE OR AC OPERATION

NATIONAL COMPANY INC.

MALDEN, MASS.

LESSON 35

Metal Locators

TYPES AND FUNCTION OF METAL LOCATORS. All devices for locating underground ore deposits, hidden treasures, explosive mines, and buried metal objects, operate on the principle that the material to be found makes the earth under the surface non-homogeneous (not the same in every way). The most often used method employs a radio transmitter and receiver and is, of course, very much electronic in character. The other types of metal locators may employ associated electronic equipment also.

The seismic method requires the setting up of a disturbance such as an explosion at some distance below the surface. With the aid of sensitive electronic amplifiers, the arrival of these disturbances at various points is recorded and this permits the determination of the location of the deposits under the earth's surface.

With the gravitational method, a sensitive pendulum is used. The magnetic method may be applied if the substances to be found contain iron, nickel, or other metals which possess magnetic properties. In trying to locate oil, the variations in temperature under the earth's surface may be used as the guide. The fact that certain substances are radioactive may be used as an aid in locating the deposits of such objects.

HETERODYNE ELECTRONIC METHOD. The equipment used for searching hidden metal objects must be portable. One must move about in the locality where the objects wanted may be located. The instrument used should indicate the relative closeness to the metal object and, thereby, lead the operator to the spot where the mine, streak of ore, or other metal deposit is hidden.

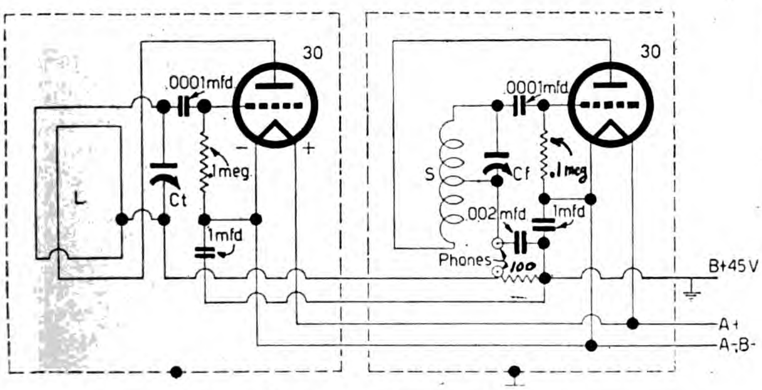


Figure 344. Schematic diagram of a simple electronic metal locator. Similar but more modern battery tubes may be used instead of type 30 tubes shown in this circuit.

One relatively simple and easily operated metal locator may consist of two basic oscillators. These should be designed to produce oscillations of about the same frequency and incorporate and adjustment in one for correcting the frequency setting. These oscillators should be completely shielded from each other and the outside.

You may be interested in using metal locators yourself, or can sell units of your own construction at a real profit to interested individuals in your locality.

A large blueprint of an electronic metal locator of tested design can be purchased from the publisher of this *course* for $1.00, postpaid. You do not need this blueprint in your studies, but may want the construction information in case you want to build a good metal locator which employs regular radio parts.

HOW THE UNIT OPERATES

The oscillators may be identical, but one must have a large loop for its coil and this loop is not shielded. The circuits used provide a small amount of coupling between the two oscillators and the frequency difference of the two oscillators produces an audible beat in a pair of headphones connected to the equipment. If the oscillators are adjusted to produce exactly the same frequency, zero-beat results (there is no frequency difference). The pitch (audio frequency) of the beat will be a measure of the frequency difference between the signals of the two oscillators.

Refer to page 247, of Volume 2, where this method for producing audio frequencies is described.

Let us assume that our oscillators with the required batteries are enclosed in a suitable portable case. The coil of one oscillator is in the form of a loop antenna. The units are adjusted for zero-beat. Under these conditions, no signal will be heard in the headphones or indicated in a sensitive A.C. meter which may be used instead. Now let us see what happens if a metal object is brought close to the loop. One oscillator is completely shielded (including its coil) and is not affected by the presence of additional metal outside of the shield. The second oscillator, however, has its loop-coil unshielded and the metal changes the inductance of the coil. But the frequency of the second oscillator is a function of the inductance of the coil and the capacity of the preset adjustable condenser. A new and somewhat different frequency will now be produced by the second oscillator. This new frequency will beat with the signals of the first oscillator and an audio note will result. The frequency of the audio note will be equal to the difference of the two frequencies. The increase in pitch will suggest the closer approach to the hidden metal when this equipment is being used in practice.

The adjustment for zero-beat is made by varying the frequency produced by one of the oscillators until it is exactly equal to the frequency of the second oscillator.

Magnetic material in the field of a coil usually raises the inductance. Non-magnetic metals placed near the coil will lower the initial inductance.

The higher the frequency employed for the oscillators, the greater will be the sensitivity of the device. At high frequencies a small value of L is used and even a tiny change in the value of L, will alter the frequency produced by a considerable amount. Frequencies from 10 to 20 megacycles are recommended.

See the formula on page 201, of Volume 2.

ULTRA-HIGH FREQUENCY PARABOLIC REFLECTOR METHOD. Radio waves of extremely high frequencies can be made to behave in a manner very similar to light. By placing the transmitting and receiving dipole antennas in separate parabolic reflectors of proper dimensions, a beam of R.F. energy can be directed at the earth. If a metal substance or deposit is present not too far below the surface, a portion of the energy will be reflected and will be picked up by the receiving antenna. The R.F. energy received is rectified with a simple crystal or diode detector and produces a direct current which operates a sensitive meter. By using different frequencies and knowing what metals form the best reflectors for any one frequency, it is possible to predict what metal probably is located under the earth being examined with this equipment.

The oscillator should produce frequencies of at least 300 MC., but 1,000 MC. would be better in order to keep the parabolic reflectors within reasonable size. Special triodes for high frequency work may be used to produce R.F. up to 500 MC. The Barkhausen-Kurtz oscillator is useful for producing ultra-high frequencies. This oscillator is operated with a negative voltage on the plate of a triode, and a positive voltage on the grid. The circuit is described in radio books of an engineering level. Of course, a magnatron or klystron oscillator may be used to generate extremely high frequencies.

An excellent book which gives a complete explanation of these oscillators and presents several practical circuits is *Ultra-High Frequency Techniques*, by Brainerd, et al.

LESSON 36

Thyratron Tubes

Comparison of a Thyratron to other Tubes. Essentially, a Thyratron* is a vacuum tube possessing a hot cathode as a source of electrons and is filled with some inert gas or mercury vapor. Very much like the high vacuum triode, it possesses a grid control element. However, because of the presence of the gas or vapor, the plate current, plate voltage characteristics are entirely different and are utilized for applications where the high-vacuum tubes would not do.

Basically, a thyratron is a gas-filled triode.

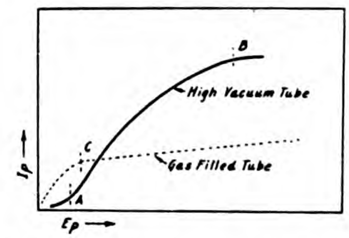
In an ordinary vacuum tube, the plate current is limited at low plate voltages by the presence of the space charge. Once the plate voltage is raised to remove the influence of the space charge, the plate current will vary with the voltage until the current will be limited by the emission.

Refer to the beginning of Lesson 9, in Volume 1, in case this is not clear to you.

In the thyratron, the action of the plate current is entirely different and is due primarily to the formation of positive ions from neutral gas atoms. These ions are very heavy by comparison to electrons (thousands of times heavier) and do not move rapidly. However, the presence of these ions permits the flow of large electron currents by altering the space potential.

When an atom looses one or more electrons, it becomes a positive ion.

In a high vacuum tube, electrons travel in a continuous path from cathode to the plate. In a gas filled tube, however, the average length of an uninterrupted path is very much shortened by the continued collision of electrons with gas molecules. These collisions result in the creation of positive ions and additional free electrons. The positive ions so formed raise the space potential and, thereby, permit more electrons to escape from the cathode. If the rate of ion generation is large, the voltage change is negligible in the space between the anode and cathode, except in the region near the cathode and the anode themselves. These regions adjacent to the two elements of the tube are subject to large potential change and are called the *sheaths,* and the region of little change is called the *plasma.*



Current variations with increasing plate potential in high vacuum and gas filled tubes. Up to point A current is limited by space-charge, after point B by limited emission. After a voltage corresponding to C, the current of a gas filled tube is almost constant.

Such a two electrode gas filled tube finds application as a rectifier of relative high current capacity and possesses a small constant voltage drop. The commercial mercury vapor tubes and mercury rectifiers of the radio type such as the 83, are examples.

Action of the Thyratron. In the thyratron, as mentioned previously, a third element, the grid, is incorporated as a means of control. The starting of the current flow between the cathode and the plate of a gas filled tube depends on the formation of positive ions in the interelectrode space. The rate of this ion formation to form the plasma is dependent on the geometrical construction of the electrodes and the applied positive plate voltage. In a two-element gas-filled tube, the anode (plate) current is started by making the anode voltage sufficiently positive to form the plasma.

Thyratron tubes are made in various sizes and in special shapes for different applications.

*The Thyratron is a trade name of General Electric Company through whose courtesy much of this information has been obtained.

HOW THE THYRATRON WORKS

In the thyratron, the grid may be used to prevent the formation of the plasma and, thereby, the starting of the current. A grid potential of a few volts may prevent the starting of an arc in a thyratron with the plate at a thousand volt potential in respect to the cathode. A change past a certain value of the grid voltage will cause the arc to start.

In a vacuum tube, the control grid element controls the plate current at all times, except beyond cut off and past saturation.

Once the current flow is started, however, the grid has no further effect on the current. It can neither limit the current, nor stop it in practical application. In practice, the grid is used either to start or prevent the starting of the discharge. The current may be stopped by sufficiently lowering the plate voltage.

In alternating current application of the thyratron, the current can only flow during the positive half of the cycle and, thereby, is interrupted as many times as the frequency of the supply voltage. Each interruption serves to restore to the grid its ability to stop the current flow. For example, if the grid should become algebraicly less than its trigger control value during the positive half of the cycle of the plate voltage, the current would continue to pass through the thyratron during the remaining period of this positive lobe of the cycle. On the appearance of the next positive lobe, however, the plasma would not be able to form because of the new value assumed by the grid, and no current would flow.

The value of the grid voltage which will just prevent the starting of the arc depends on the plate voltage and the construction of the particular thyratron.

The trigger point has been used in the sense as the minimum value of the grid voltage that will prevent the starting of the arc. An increase in the positive direction of the grid voltage will allow the formation of the plasma if sufficient anode voltage is present.

Make a few more curves of his type for other relationships between the grid and plate voltages.

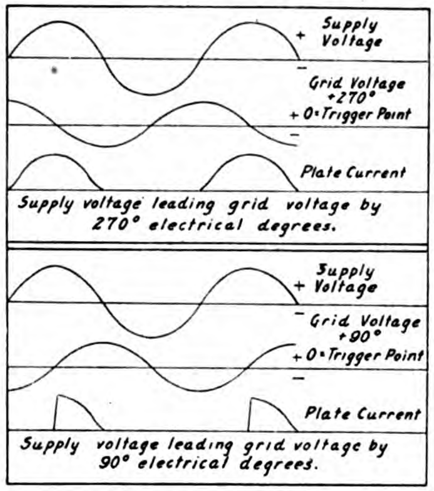


Figure 345. The above graphs show the relationship between the supply and grid voltages, and the plate current, for two different conditions of operation of a thyratron tube.

The average output from a thyratron may be varied by making the grid pass its trigger point during some period of the positive plate voltage cycle other than the very beginning. By operating the grid with alternating current voltage of the same frequency as the plate supply voltage and proper magnitude, the power output may be varied from the maximum to zero by changing the phase difference between grid and plate voltages. The figure illustrates this procedure for two different phases.

Thyratron tubes may be used as inverters of D.C. to A.C. without any mechanical moving parts and with little loss of voltage.

LESSON 37

Motor Control

Purpose and Application. With the aid of electronic equipment it is possible to adjust, keep constant, automatically vary or control the speed of electric motors. Let us consider a single application of each of these requirements. The speed of certain D.C. and A.C. motors may be easily varied with the aid of electronic equipment. But because the same effects (perhaps not to the same fine degree) can be accomplished by simpler mechanical means, electronic devices are more often used to keep motors running at a constant speed although variation in the supply voltage and load may occur. A fan or pump may require constant speed rotation. Several motors employed in sections of paper-machine drives, continuous rod and strip mills, or galvanizing machines must be synchronized to rotate at exactly the same speed, and electronic equipment using electron tubes is adaptable for this purpose. In rolling up wire, fabric, or rope, the speed of the *wind-up* reel must be reduced as the material *forms* away from the center at a faster rate because of greater diameter. The motors used to raise an elevator car may be started and accelerated at the fastest rate in keeping with the comfort of the passengers when electronic control is incorporated. Further, such automatic control may be used to level the car in line with the floor by stopping the motors at the proper instant.

You probably experienced this effect in winding string on a spool or rolling a snowball.

You may realize that photo-cells or inductively-coupled circuits are employed to register the actual position of the elevator car at the moment, but the motors used to lift the car must be controlled electronically to accomplish this objective.

How the Motors are Controlled. Although in certain controlled applications, the motors need only be started and stopped by the associated electronic equipment, in majority of installations the speed of the motors must be varied or controlled in a required manner. For most applications, the voltage for the field of the motor or the voltage for the field and armature are supplied by thyratron tubes and this voltage is, therefore, easily controlled. Various arrangements of thyratron tubes may be employed, but in all cases the changing of the phase angle (time relationship) between the grid and plate voltage will permit the control of the current through the tubes from *full on* to practically zero. The required phase-shift may be obtained with the aid of a resistance-reactance bridge which permits the phase relation of the grid voltage to be varied with respect to the anode voltage.

These thyratrons, in turn, must be controlled electronically from the "adjustment" to be achieved.

How the Phase-Shift is Controlled. To obtain the needed control either the resistance or the reactance of the bridge must be varied at a rate to give the required results. Mechanical means may be employed to couple back to the bridge some mechanical motion which is due to the incorrect operation requiring correction. This motion is used to bring about the needed change in the resistance-reactance ratio of the bridge. A movable-core reactor or a carbon-pile rheostat could be used in such a way. A supplementary small generator could be driven from the motor, and the voltage generated used to unbalance the bridge in the required manner.

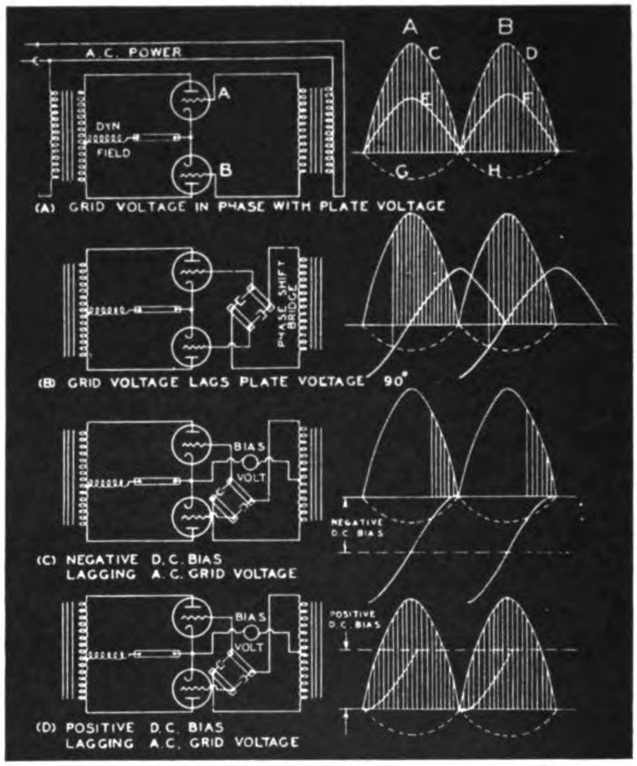
The action of the phase-shifting network can be supplemented with an adjustable bias voltage which will also exercise control by

CIRCUITS EMPLOYED

changing the effect of the network. This bias voltage may be of a variable type and can be easily controlled by one or more receiving type vacuum tubes. These tubes in turn can be controlled by some mechanical motion of the system. For example, plate current can be changed by using the tube in an oscillator circuit and detuning the circuit by means of a moving metal shield near the coil (inductance) of the oscillator. Or perhaps a photo-cell can be used.

The addition of a non-magnetic metal material in the vicinity of the coil lowers the inductance.

The bridge may be made up of two capacity reactances and two resistive members. Notice the different symbols employed for capacity, and rectangular symbols for resistance.



Reproduced through the courtesy of General Electric Co. and reprinted from "Automotive Industries."

Figure 346. Illustration of a basic circuit for controlling the speed of dynamometers used in research work and tests. The current supplied to the component marked DYN FIELD is easily controlled as shown, and can be applied to other equipment.

Refer to the drawing on this page in reading this text.

How the Thyratron Phase-Shift Circuit Operates. One method for adjusting the resulting current is by changing the grid bias with the aid of a phase-shifting bridge and a controllable D.C. voltage, as shown in the above figure. In part (B) of the figure, the phase-shifting bridge displaces the grid voltage wave about 90 electrical degrees, causing the tube to *fire* somewhat later in the half-cycle, with a resulting lower current in output. The circuit shown under (C) has a negative D.C. voltage in the grid circuit, which offsets the A.C. grid voltage wave by the amount of the D.C. voltage without changing the phase relationship of the grid voltage to the plate voltage. The grid voltage curve crosses the critical firing line toward the end of the cycle and, consequently, only a small current passes. Similarly, as shown in part (D), a positive voltage is applied, the grid bias voltage curve crosses the firing voltage line early in the half-cycle, and the current is maximum.

LESSON 38

Power Rectification

Tubes Employed. In connection with our studies of radio power supplies, we have learned about vacuum tube rectifiers of small size (up to about 50 watts D.C.). The usual electronic tube used for rectification is a diode. A cathode of this tube supplies electrons which are attracted toward the anode when the latter is positive with respect to the cathode. The cathode element may be the actual filament, a heater type of cathode, a pool of mercury, or even a cold cathode.*

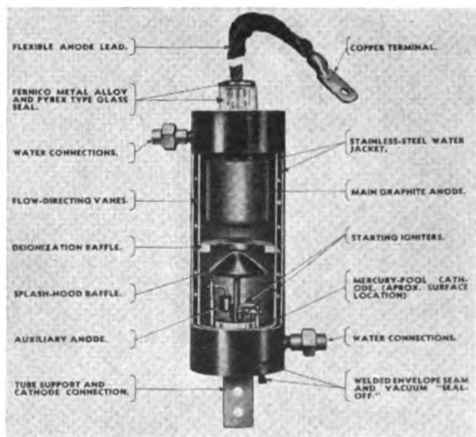
The student must realize that extensive application is made of electron tubes for power rectification and that this is an important branch of electronics.

In some rectifier tubes a gas at low pressure is introduced. Argon, neon, or helium may be used, but usually the partial atmosphere is supplied by mercury vapor secured from a few drops of mercury in the envelope which vaporizes when the cathode heats up. As already explained on page 309, in a tube which contains gas the space charge, which is the factor that limits the plate current in a vacuum type tube, is neutralized by the positive ions. These positive ions are present in a mercury rectifier and are produced by the collisions between the electrons and mercury atoms. This action results in a low voltage drop in the tube — about 15 volts in mercury tubes. Further, gaseous rectifiers produce a low voltage drop which is practically independent of the current taken from the tube.

Gases which do not react easily with other substances are used.

Compare the characteristics of radio rectifier tubes 83 (mercury vapor) and 83V which is similar but of a vacuum type. Use the charts of Lesson 9. Do your findings agree with the text explanation?

Gaseous rectifiers may be made to carry very high currents since the voltage drop and the related power dissipation within the tube are relatively low. Where very high current is to be rectified, special tubes such as *General Electric* water-cooled *ignitrons* are used. Basically, an ignitron rectifier consists of a pool of mercury placed in an evacuated vessel, a resistive material such as silicon carbide or boron carbide dipping into the mercury, a closely located anode, and associated auxiliary components. By passing current from the resistive material to the mercury pool, an arc is forced. At a definite value of voltage and current, a spark occurs at this junction and produces a cathode spot. If the anode is *positive* at this time, conduction will take place. The advantage lies in the resulting high emission, high overload capacity, and the control feature which permits the starting of the action during the required instant of the positive half of each cycle.



Courtesy General Electric Co.
Figure 347. A cross section view of a sealed-ignitron tube, giving the names of parts.

Requirements and Applications. For many industrial requirements D.C. is needed. Alternating current is easier to generate and is more economical to transmit over long distances. In practice, A.C. is generated at medium voltages, stepped up with transformers to very high voltages which are transmitted over power lines, and these voltages are stepped down at the destination. With very high voltages, to obtain a given amount of power very low current is needed. Since the size of the conductor used depends on current (and not voltage), a great deal of copper is saved in high tension wires. D.C. cannot be stepped up at all, and considerable power loss occurs when D.C. is reduced in voltage.

(*Continued on page* 318)

*Rectifier tube, type OZ4, is of the cold cathode type.

LESSON 39

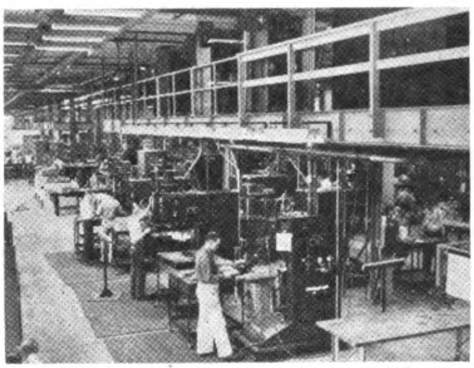
Welding Controls*

Electronic controls are used extensively in connection with resistance welding equipment. The principles involved can be easily understood by a radio technician.

Basic Facts About Welding. The development of controls for resistance welding machines was one of the earliest achievements of electronic engineers in the industrial field. Resistance welding is one of a number of methods of fusing metals together. Others are brazing and soldering, arc welding, torch welding, and hot forging. Resistance welding consists of applying pressure by means of copper alloy electrodes to two or more pieces of metal and then heating the adjoining surfaces of the work to the fusion or melting temperature by allowing electric current of a definite magnitude to pass through the pieces for a definite length of time. When the current flow is stopped, with pressure still maintained, the melted metal "freezes," binding the pieces together as a single unit.

Although there are many forms of resistance welding, such as spot welding, projection welding, pulsation welding, and seam welding, the basic method in all cases is the same. The nature of the weld depends upon such factors as electrode pressure, size and shape; type, thickness, and surface condition of metal to be welded; time of current flow, and the magnitude of this current. The last two factors can be controlled electronically, while the others are subject to mechanical control. There are at the present time two basic methods of obtaining the necessary welding current. These are the A.C. and the stored-energy methods.

See the chart on the next page.



Courtesy General Electric Co.

Figure 348. A battery of A.C. spot-welding machines used in aircraft work. The high voltage control panels are placed on the balcony.

A.C. Resistance Welding. The actual welding current required to melt or fuse two pieces together depends upon the type of metal being welded and its thickness. When welding high-resistance metals such as stainless steel of thin gauge, only a few thousand amperes are required. When low-resistance materials such as aluminum alloys are welded, 20,000 to 60,000 amperes are required.

The simplest and oldest method of obtaining this current is by means of a step-down transformer (welding transformer), the primary of which is connected through an interrupting device to the plant electric power distribution system operating at 220, 440, or 550 volts. Even though a step-down transformer is used, the primary current may still be several thousand amperes. Prior to the introduction of electronic control, mechanical devices were used to make and break this current.

Notice the many advantages of electronic controls.

The problem of mechanically making and breaking such a current from 50 to 1,200 times per minute without excessive maintenance is a real task. For uniform results, the welding circuit must be closed consistently not only for a definite length of time but also, to obtain consistent values of welding current, at a definite point on the A.C. voltage wave. Electronic control assists materially in obtaining consistent results because it is without inertia and friction and can control precisely the start and finish of welding current. In addition, since electronic control has no moving parts or arcing contacts, maintenance time and expense are much less.

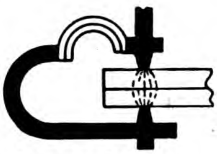
*Material of this lesson is reprinted from parts of an article by G. W. Garman, with the permission of the *General Electric Company*.

SEQUENCE OF SPOT-WELDING MACHINE

1. SQUEEZE TIME.* This is the interval between the application of pressure and welding current. When the welder initiating switch is closed, the squeeze-timer and the electrically operated valve are simultaneously energized. The delay before initiating the weld time is to allow the electrodes to exert full pressure on the work before current flow starts.

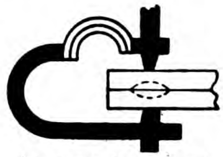
Electrodes close

2. WELD TIME. For spot welding, this is the interval during which current is allowed to flow through the work. For pulsation welding, the **weld interval** is that interval during which current is intermittently applied to the welder. Each current-flow interval is called **heat time.†** Each interval during which no current flows (during the weld interval) is termed **cool time.**



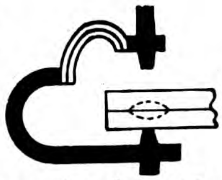
Current flows

3. HOLD TIME. This is the interval during which the electrodes are held on the work after completion of the weld time. This allows the weld to freeze, or harden, under pressure, and, because of the cooling effect of the water-cooled electrode, minimizes surface oxidation.



Metal freezes

4. OFF TIME. This is the interval during which the electrically operated valve or pressure mechanism is not energized. This **off time** is, therefore, the delay after the **hold time,** before the sequence is repeated. The **off-time** timer provides the automatic-repeat feature, when the operator keeps the initiating switch closed. Panels that include the **off time** also include a switch to permit selection of automatic-repeat and non-repeat operation.



Electrodes open

* *When a two-stage foot switch is used, only the electrically operated valve will be energized by closing the first weld-initiating contact. If the second contact is then closed, the normal sequence will be carried out. If the first initiating contact is opened without closing the second contact, the electrically operated valve will be de-energized.*

† *When a sequence timer is used with synchronous electronic controls, the* weld (or **heat**) *time is determined by the control not by the timer.*

The above chart is published through the courtesy of *General Electric Co.*

Early Electronic Controls. With the general adoption of electronic control some 12 years ago, the only tubes available which were economically justified were the hot-cathode thyratrons. These had limited ratings up to 12½ amperes but could be operated with as high as 6,600 volts. With many applications requiring control of several hundred amperes, the logical procedure was to use a so-called "series transformer." The primary, or low-voltage winding of this transformer was connected in series with the primary of the welding transformer. When the thyratrons connected across the high-voltage winding were allowed to pass current, the transformer was effectively short circuited, allowing substantially full voltage to be impressed on the primary of the welding transformer. With the thyratrons shut off or prevented from passing current, the impedance of the primary winding was sufficient to allow only a small voltage to be impressed on the welding transformer. Even though this equipment was relatively expensive and bulky, and was limited to the control of a welding load of about 350 kilowatts maximum with a single pair of tubes, it was used extensively, particularly for seam welding of gasoline tanks, refrigerators, and similar products.

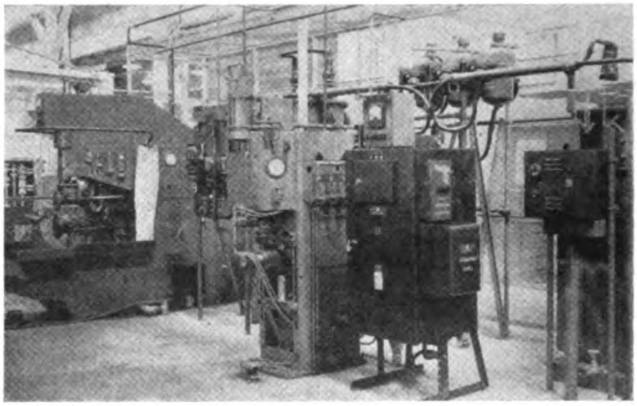
Make a drawing of this welding control circuit.

It was, however, this type of control combined with an electronic timing circuit that demonstrated the full advantages of controlling welding current precisely and proved that a resistance welding machine with the proper type of control was a precision machine tool.

Ignitron Tube Controls. With the development of the sealed-off water-cooled ignitron tube, the limitation of price and size of electronic control was removed. In addition, while the previous control using a single pair of tubes was limited to 350 kilowatts, the water-cooled tubes could control for short periods of time approximately 2,000 kilowatts. Furthermore, even without the precise timing and control feature, two of these tubes could be con-

We have studied about these tubes in the previous lesson.

nected as a single-pole electronic switch or contactor. Such a contactor had the advantages of long life, low maintenance, and silent operation. Prior to the war, hundreds of these contactors were installed in the automobile industry. A survey indicated they were adapted particularly for high-speed or heavy-welding current applications.



Courtesy "Radio News" Magazine

Figure 349. A view of 200 kilowatt seam-welding machine and a 75 kilowatt welding press.

The trend is toward the incorporation of the timing control, circuit breakers, sequence controls, and other apparatus in the welding machine. This saves floor space and simplifies servicing.

Simplification of the Adjustments. Prior to the introduction of electronic control, welding current was adjusted by the use of taps on the welding transformer. The necessary tap switches were bulky and, unless an excessive number of taps were used, the steps of adjustment were relatively coarse. Since with electronic control it is possible to control the starting of each half-cycle of current, the *phase-shifting* method of heat control was developed. With this method, a small potentiometer is used for adjustment of the current indirectly and can be quickly and easily controlled with a fineness of adjustment that cannot be obtained with any other practical method.

(*Continued from page* 315.)

An electric locomotive, using D.C. obtained with the aid of ignitron tubes, is shown leaving a mine tunnel.

Figure 350. Electrically powered locomotives are usually D.C. operated, and the unit illustrated is used in mines. With the aid of power rectification equipment, the more economically *supplied* A.C. can be converted to the required direct current. *Courtesy General Electric Co.*

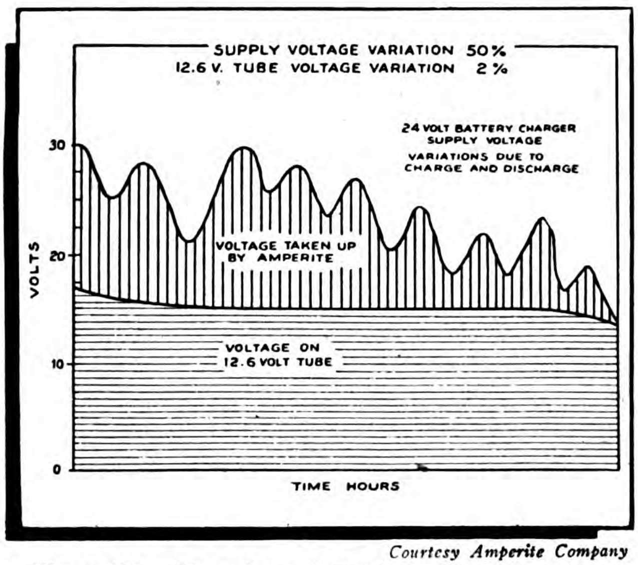
For electro-plating, variable-speed motors, and other requirements, D.C. is essential. Power may be delivered in A.C. form, at high (economical) voltages, and stepped down and rectified at the locality where D.C. is needed. Ignitron tubes may be used for this purpose. Ignitrons are also used in welding equipment where the welding time must be accurately controlled.

LESSON 40

Voltage Regulator Tubes

PURPOSE AND CONSTRUCTION. Automatic ballast-regulating tubes are intended to keep the current in a circuit at a definite value. Units of the *Amperite* make are made in various sizes and are designed for this purpose. A certain voltage drop occurs in the resistance element of the ballast tube. Should the supply voltage increase, the ballast tube will automatically increase its resistance, thereby taking up the additional voltage and keeping the voltage on the load at a constant value. A typical installation may consist of a 12.6 volt tube connected to a source of voltage which has considerable variation. As shown in the graph, for extreme variations of 50% in the supply voltage, the voltage delivered to the tube remains within 2% of the rated value.

Tubes of this type are also used in special bridge oscillators to keep the frequency variation to a very low figure.



Courtesy Amperite Company

Figure 351. The voltage fluctuations of a battery-charger system can be eliminated and a constant value of voltage delivered with the aid of an *Amperite* ballast tube.

This graph shows the action of a typical *Amperite*. Suitable ballast-regulating tubes are available for controlling voltages in any other range.

The *Amperite* ballast tube consists of an iron wire hermetically sealed inside of the bulb which contains hydrogen or helium. These gases have high heat constructivity. The wire employed has a high temperature coefficient and this causes large variations in the apparent resistance, for relatively small changes of current passing through the wire. This action is further helped by the very rapid cooling of the gas used which flattens or extends the regulating characteristics.

An increase in the supply voltages will tend to increase the current. The slightest increase in current will cause the wire to heat up to a larger extent and, thereby, increase its resistance. This action will limit the current and produce a larger voltage drop in the wire of the tube.

APPLICATION. Automatic ballast tubes may be compared to a tungsten lamp which also has characteristics that tend to keep the current constant. These tubes are constant current devices and are, therefore, used to regulate a constant load; i.e., one having fixed wattage consumption.

This graph shows the value of current through the ballast tube when different voltages are applied to the terminals. The current in a D.C. circuit is equal to E/R. If E changes and the resulting current must remain almost constant, the R (equivalent resistance of the ballast tube) must change in step with the voltage.

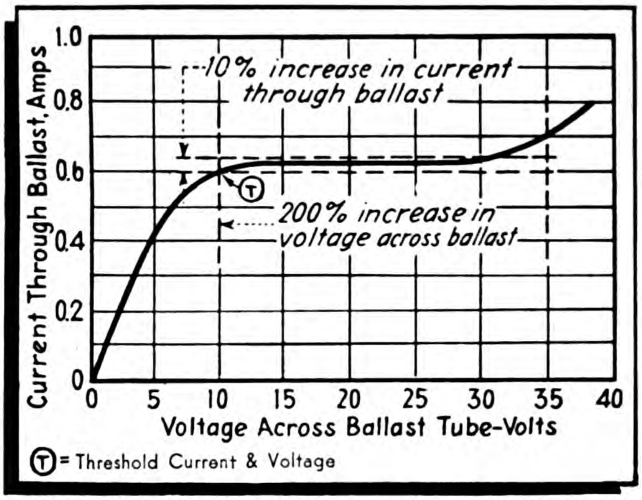


Figure 352. Characteristic curves of a typical *Amperite* ballast tube showing the effect in keeping the current constant with variation in the input voltage.

Tubes for other voltages behave in a similar manner.

Notice the behavior of an *Amperite* ballast tube, as indicated in the graph. The current supplied tends to remain at a constant value although the voltage for the particular tube covered by the graph, may increase from 10 to 30 volts. Very good regulation can be obtained by using an *Amperite* bulb and a neon lamp.

In applications where the load varies, electronic regulators involving more complex circuits are required.

The voltage across an argon or neon bulb remains the same when the bulb is connected in series with a resistor across a variable voltage source. This action is combined with an *Amperite* ballast tube to produce an output voltage with less than 2% variation while the input line voltage varies as much as 62%.

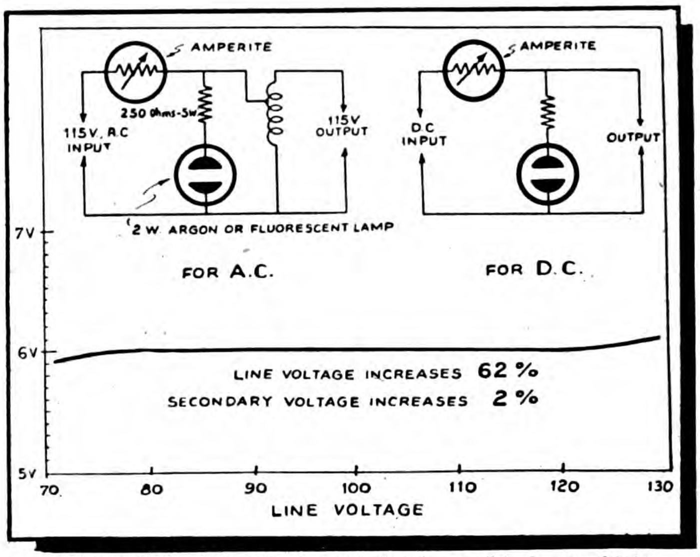


Figure 353. Very close regulation is possible by combining an *Amperite* ballast tube and a gas-filled tube in a suitable circuit.

Review Questions and Problems. 1. Name several applications of voltage regulator tubes. Describe a constant voltage requirement where a tube of this type would not be applicable.

2. Explain the function of the circuit where a ballast tube and a neon bulb are used.

LESSON 41

Uses of X-rays in Industry and Medicine

NATURE AND PROPERTIES OF X-RAYS. The historical discovery and early experiments with X-rays are of little interest to the practical technician. It is sufficient to say that in 1895, Roentgen, while studying electrical discharges in a diode gas-filled tube, observed that certain chemicals glowed even when this diode tube was completely enclosed in black paper. Later studies indicated that the radiation given off by this tube affected photographic film and would penetrate flesh, wood, and thin pieces of metal. The early tubes used a cold (not heated) cathode and a high positive potential was placed on the anode. The radiation, in these early tubes came from the glass walls, but later a metal target was added. In 1913, Coolidge introduced a hot cathode resulting in much greater efficiency.

The discovery of X-rays was accidental.

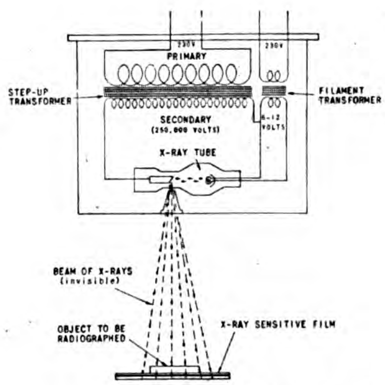
X-rays are produced when high velocity electrons traveling in the tube are stopped upon striking a solid object. The wavelengths produced depend upon the velocity of the electrons which strike the target. The intensity depends upon the number of electrons that strike the target. To produce higher intensity the voltage used must be increased and this also causes the electrons to acquire higher velocity; i. e., produce shorter wavelength radiation.

The velocity of the electrons is a function of the anode voltage.

To measure very short wavelengths, a unit known as the *Angstrom* is used. One Angstrom unit represents a very short distance, being equal to 1/100,000,000 centimeter,* or 10^{-8} cm. The way the energy is distributed among the possible wavelengths depends on the characteristics of the substance hit. The value of the shortest wavelength produced is a function of the applied voltage. For example, this shortest wavelength for 100 kilovolts corresponds to .12 Angstrom units, .04 units for 300 kv., and .02 for 600 kv.

The intensity of the rays is reduced as they proceed away from the source. This reduction in intensity follows the inverse-square law. This means that a group of X-rays which have spread out to one square unit at a unit distance from the source, will spread out to four square units at two units distance, and to nine square units at three units distance. The intensity is also reduced by the absorption in any materials in the path of the X-rays.

X-RAY GENERATORS. An X-ray tube requires a filament voltage and a plate potential. If A.C. is applied to the anode, the X-ray tube serves as the rectifier, but better efficiency can be obtained if a separate rectifier is employed. A typical circuit is illustrated.



Drawing courtesy of General Electric X-ray Corp.

Figure 354. A diagram of a simple type of X-ray generator showing the connection of the essential components.

INDUSTRIAL APPLICATIONS. The use of X-rays in industry for checking welds and inspecting castings is not new. Modern high voltage machines are compact and are designed for easy portability and simplicity of operation. X-rays reveal such faults as blow

*100 centimeters equal one meter. From this you can calculate that 10^{10} Amgstrom units equal one meter.

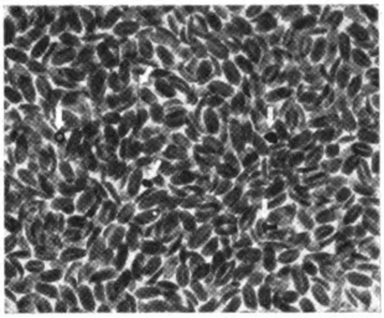


Figure 355. An X-ray photograph of a bag of peanuts showing foreign metal parts which should be removed. X-rays are used for inspection of materials which may be enclosed in containers.

In certain Army transmitters crystals of great accuracy are required. The speeding up of crystal manufacture with the aid of X-rays helped manufacturers meet the increasing demand.

holes, tears, shrinkage cavities, inclusions, and internal cracks — faults often present in metal parts and not detectable by any other means except by the actual failure of the part in service. Parts made of various steels, ferrous alloys, and aluminum may be inspected with the aid of X-rays.

Units employing up to a million volt supplies are used for the inspection of large metal pieces and for applications where the surfaces of the objects to be examined are irregular and sharp pictures (for radiographic inspection) are required. X-ray equipment employing tubes of lower operating voltages find extensive application for other inspection jobs. X-rays have been used to determine the quality of oranges, the nature of the contents of a sealed bag, the uniformity of the copper conductor inside the rubber and cloth insulation, the *fit* of metal parts, and for many other unusual applications.

Figure 356. The illustration shows the use of a large machine of *General Electric* make being employed to detect possible imperfections and internal cracks in a large casting.

A crystal cut from quartz has a temperature coefficient which depends on the orientation (relative position) with respect to the crystallographic axes of the quartz. Certain type of cuts have minimum frequency variation with temperature and are required for many uses. An X-ray diffraction instrument is available which will measure directly the error in the angle of cut of a trial crystal wafer. Without taking the time to finish the trial wafer, the orientation of the *mother* quartz on the saw table could be corrected for the error found. The blanks cut after this simple adjustment would be of the required type. This test would require a few minutes as compared to the old tests which called for complete grinding of the test crystal and checking of the results.

X-rays are used also for analysis of the chemical properties of various substances. Qualitatively the use of X-rays indicates the presence or absence of elements. The atoms of various elements form different patterns on a photographic plate and each element has its characteristic X-ray spectrum.

APPLICATIONS IN MEDICINE. X-rays are used for diagnosis and for therapeutic treatment. The diagnostic units are designed for easy movement of the table, the tube housing, and the screen.

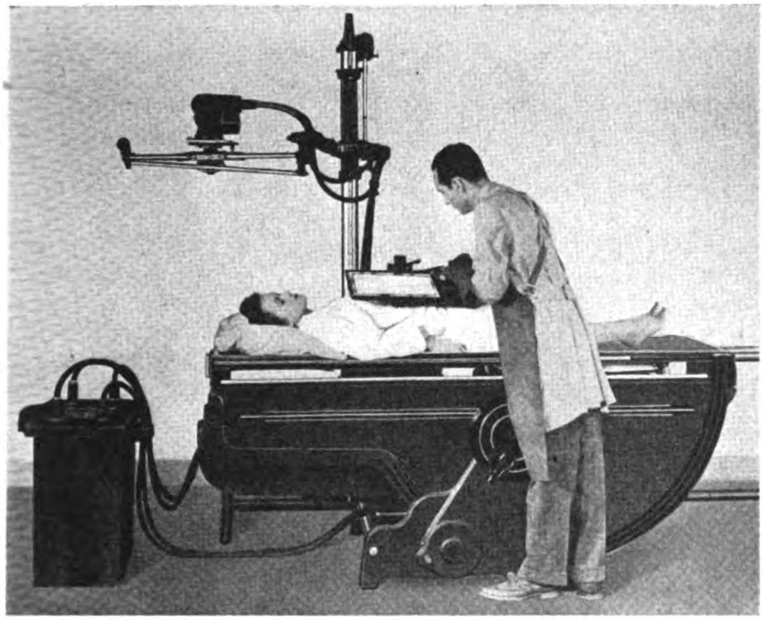


Figure 357. X-rays are used in medicine for diagnosis and for treatment.

A unit made by *General Electric X-ray Corp.* is illustrated. Other X-ray generators, usually operated at higher voltages, are used for therapy.

Usually the same unit may be employed for radiographic (picture) and fluoroscopic (visual) diagnosis. The therapy units are operated at higher voltages and, in practice, adjusted to deliver the beam of X-rays to a small section of the body. X-rays have been used for treatment of certain mental cases and for physical ailments.

For skin treatment, rays produced with 135 to 300 kilovolts are employed. A filter consisting of a thin sheet of aluminum (several millimeters thick) is placed between the source of the rays and the patient. A still thinner filter of copper may be used instead. Such a filter absorbs a great deal of the low frequency radiation that otherwise would be absorbed by the skin.

In an X-ray therapy unit of the *General Electric* make, a light and a reflector are incorporated in the housing, and the light beam produced is adjusted to coincide with the invisible X-ray beam. This permits correct placement of the equipment to give needed results.

You understand, of course, that X-rays are not visible.

The film used in connection with X-ray equipment is placed in a light-tight cassette (special box-like container) which has a front plate of thin bakelite or aluminum. Intensifying screens are placed inside the cassette, on both sides of the film and in close contact with it. These screens are coated with chemicals which produce light when the X-rays strike them. Although the actual X-rays do have a small effect on the photographic film or plate, the main action on the film is due to these light radiations.

Servicing Suggestions. The usual X-ray equipment in use in doctors' offices, hospitals, and industrial plants, are bulky affairs, but the circuits are relatively simple. The circuit of the unit is supplied by some manufacturers. In a few cases, you may have to trace out the entire circuit. The tests should be made with an ohmmeter while the equipment is turned "off." Extremely high voltages are present with the equipment in operation. If you wish to make a trial test, place the equipment back in place, connect all safety features included in the circuit, and operate the equipment in the usual manner.

Remember that the circuits are simple and the voltages are high.

LESSON 42

Ultra High Frequencies Concepts

Frequencies above 100 megacycles are becoming more important daily. These high frequencies are used and are especially well adapted for television transmission, frequency modulation, and radar.

In conducting electical energy some loss is always present. The same arrangement may produce different losses for various frequencies.

Make sketches of these explanations. They will help you to grasp these ideas.

Electron transit time is not considered in dealing with audio and low radio frequencies.

A triode oscillator must provide some *gain* in order to function. More energy must be delivered to the plate circuit than is used up by the grid circuit.

Behavior of Ultra High Frequencies. The notion that electric current flows *in* a conductor must be dismissed in dealing with extremely high frequencies. Due to *skin effect* which has been explained earlier, the current at high frequencies has a tendency to travel on the surface of the conductor. At frequencies, in the order of one billion cycles, the current flows almost entirely on the surface. Since the surface serves only to conduct and guide the current and the associated energy, then the conductors are only boundaries. The actual energy is stored and exists in the associated electro-magnetic fields.

Energy at ultra high frequencies can be conducted with the least loss through rectangular or cylindrical wave guides where the metal walls serve simply as boundaries. Further, such boundary cavities can be made to serve as resonators taking the place of the conventional inductance-capacitance circuits which are used for lower radio frequencies. The similarity between such a cavity resonator, perhaps in the shape of a cylindrical can, and the more familiar L-C tank circuit can be grasped in this manner. An inductance of a very low value may consist of one turn. A small capacity may be made from two small plates. Consider small sections (minute elements) of the wire loop serving as these plates. The single loop making up this inductance has many small condensers which exist between each pair of small sections of all parts of the loop. We can place many loops above each other and connect them together at all points. The total resulting inductance will be somewhat reduced, the capacity effects increased. The resulting cylindrical *can* formed from these loops will serve as the L-C circuit.

Limitations of a Triode as an Oscillator. In studying the action of electrons in vacuum tubes, we assumed that the movement was instantaneous. The instant the control grid changed its potential due to the exciting signal, the plate current (i.e. the number of electrons reaching the plate) correspondingly changed. This is essentially true for audio and the lower radio frequencies. At extremely high radio frequencies, however, the time required for the electrons to traverse the space from the cathode to the plate must be taken into account. At ultra high frequencies, the control grid may have several changes of potential during the time an electron takes to complete its journey to the plate. In a triode used as an oscillator for very high frequencies (say about 150 MC.), a group of the free electrons will move through the space trying to follow the effects of the potential assumed by the control grid, but being *called back* before reaching the plate. At somewhat higher frequencies, so few electrons will reach the plate that no oscillation can be obtained. Close spacing of the elements in special high frequency tubes permits the handling of frequencies up to 600 MC., but at reduced power level.

(*Continued on page* 332)

LESSON 43

Electron Microscope

NEED FOR HIGHER MAGNIFYING POWER. In the 17th century, lenses were arranged to serve as the first microscope. The science of medicine was revolutionized when it was discovered that many diseases were caused by bacteria which could be seen under the microscope but whose existence has not been suspected previously. As the regular type of microscope became more generally used, it became apparent that there were many things too small to be seen even with the finest instruments. We now know that this limitation is not due to the lack of skill on the part of the designer but to the very nature of *light*. *Resolving power* is a technical word for the power of being able to discriminate between two very small objects which are close together. Besides other technical factors, resolving power depends on the wavelength of the light used for observation. Since ultra-violet light is of a smaller wavelength than visible light, it has been used for photographic specimens not to be seen with ordinary visible light. Under the most favorable conditions, the discrimination of objects separated by less than 0.1 micron (a micron is about 1/25,000 of an inch) is not possible. This corresponds to magnification of about 3,000 diameters.

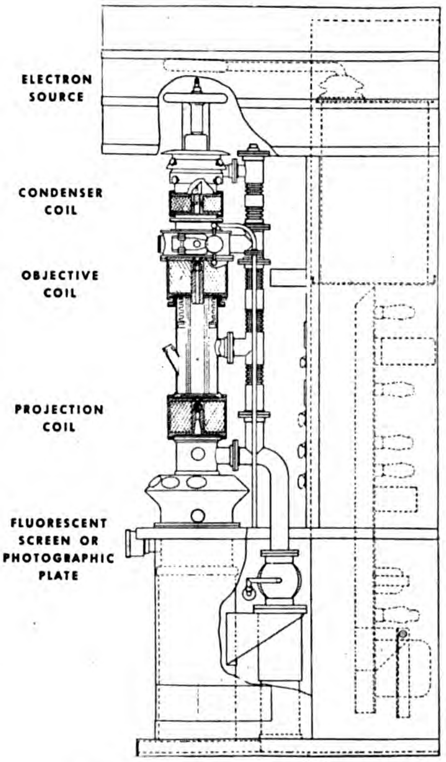
The seriousness of this limitation was evident to the bacteriologist who realized that many tiny and unseen particles were the cause of many ailments. In the industrial fields, certain limitations on the study of colloids and finely divided particles were also present. The use of X-rays permitted the photographing of somewhat smaller objects, but the need was for visual observations of objects requiring direct magnification of 10,000 to 30,000 diameters. Such magnification was made possible with the electron microscope and photographic enlargements can be used to increase the magnification to a total of 200,000 times life-size.

ELECTRON OPTICS. There is a close analogy in the behavior of light and electrons. The main similarity, of importance to us, lies in the action of lenses on light as compared to electric fields influencing the motion of electron streams. Electron optics are used in all cathode ray tubes to fashion a pencil of electrons from the wide stream emitted from the cathode gun. The science of electron optics has made possible the electron microscope. In an electron microscope we are able to make highly magnified images with such an electron optical system by combining two or more electronic "lenses." The great advantage of such a microscope lies in the fact that we are no longer limited by the wavelength of visible light. Under the application of 100,000 volts, the wavelength action of an electron is only 1/100,000th of the wavelength of visible light. The present instruments have permitted examination of such tiny particles as the tobacco mosaic virus which is rod-shaped and is about 1/100,000th an inch long.

DESCRIPTION OF THE RCA ELECTRON MICROSCOPE.* A high power electron microscope for observation by transmission is con-

*This description is reprinted in part from "Electron Microscope," a booklet issued by *RCA Manufacturing Co., Inc.*

The electron microscope is an outstanding achievement in the field of electronics. The operating principles of the electron microscope are similar to some of the functions of a cathode ray tube described in Lesson 19.



Simplified drawing showing the construction of the electron microscope.

Figure 359. A complete view of an RCA electron microscope in application. Notice the six observation windows.

structed with the same types of essential elements as a light microscope. Light microscopes consist of a light source (often separate from the microscope, but built into one unit on modern instruments); a condenser lens which concentrates the light beam on the specimen; a stage, with an adjusting motion; and an eyepiece for visual observation or a projection lens for recording on a photographic plate. A similar nomenclature is used to define the different elements of an electron microscope, the only difference being that every *light* element is replaced by a corresponding *electronic* element. Thus the light source becomes an electron source; and lenses become suitably shaped fields. Elements like the stage appear quite different because of the necessity for operating in vacuum. This is easy to understand since electrons can travel without hindrance only in a vacuum and their paths are altered by any material object and, therefore, the usual glass slides of light microscopes cannot be used.

Courtesy of RCA

Figure 358. An electron "photograph" or micrograph of zinc oxide smoke magnified about 22,000 diameters.

Its manipulation differs somewhat from that of a light microscope. In the light microscope we have a fixed optical system which can be moved up and down, and focusing is done by changing the position of the specimen with respect to the lenses. In the electron microscope, we have constant distances and the lens power is varied. This can be done because the lenses are created, in the case of magnetic optics, by a current flowing through a coil.

The RCA electron microscope is a very compact, self-contained instrument. The electron source is operated at voltages between 30,000 and 60,000, and, to provide ample protection of the operator from the high voltage and X-rays, is enclosed in a lead encased upper hood. The electron beam coming from this source is concentrated on the specimen by the field produced in the condenser lens coil. The specimen, which is supported on a very thin nitrocellulose membrane suspended across the opening of a fine mesh screen, is clamped in the tip of a cartridge very close to the second field lens produced in the objective coil. A plate which supports the specimen cartridge constitutes the movable stage. The specimen motion is transmitted to this plate from the exterior of the evacuated system by means of fine screws and metal flexible bellows. The electrons, after passing through the specimen, are focused by the object lens coil into an intermediate image and the projection lens coil produces a further magnified image on the large fluorescent screen in the final viewing chamber. Six observation windows, which are placed to allow binocular vision for careful observation, enable a number of spectators to view the image simultaneously. After a selected field of view is focused, and the magnification adjusted to the desired value, a photographic record may be made by merely removing the fluorescent screen and allowing the electron image to strike a photographic plate, which is carried in a holder in the vacuum, immediately below the screen.

These windows are visible in the photograph above.

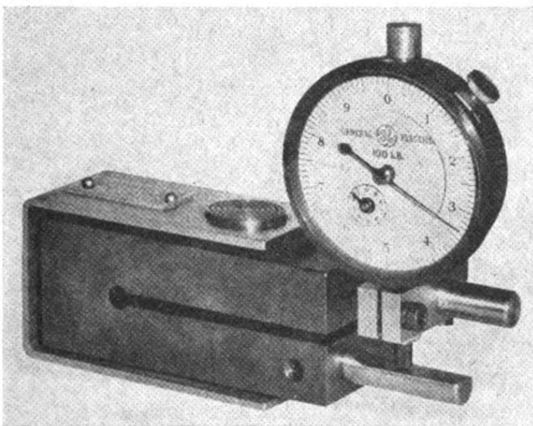
LESSON 44

Electric Strain Gages*

Purpose and Function. The usual electric strain gage is fundamentally an A.C. bridge circuit in which one or more impedance branches are acted upon by the quantity to be measured. The calibrated amount of bridge unbalance is indicated on an instrument which may be remotely installed at any convenient location. Electronic tubes are used to amplify the sensitivity of the equipment and to stabilize input voltage.

With some exceptions, reactance-type gage elements serve as the active bridge members. Whenever their application is possible, gage elements of this type are preferred over elements of other types because of their relatively low inherent impedance, large useful range, good stability, and immunity to electrostatic and magnetic interference effects.

A bridge circuit consists of four reactive or resistance arms of suitable values to produce zero voltage across an indicating device. Usually, one or more arms of the bridge may be adjusted to produce the needed balance. The impedance of one arm is varied under stress and, in this manner, the variation produces a voltage change.



Courtesy General Electric Co.

Figure 360. A view of an electronic gage employed for indicating the pressure between the electrodes of a welding machine. This gage will indicate forces applied to the pressure pads up to 4,500 lbs., with each small division representing 10 lbs.

The indicating instrument may be calibrated in suitable units—pounds of pressure in this case.

Design and Sensitivity. In its simplest form an active electromagnetic impedance element consists, for example, of a U-shaped iron yoke and an iron armature placed near the open ends of the U, leaving small air gaps. A coil is placed on the iron yoke and is connected in the A.C. bridge circuit. It is evident that when the air gap between the iron yoke and the armature decreases, the reactance of the coil increases. In this case, the bridge output is a function of the armature displacement and may therefore be calibrated in terms of this displacement.

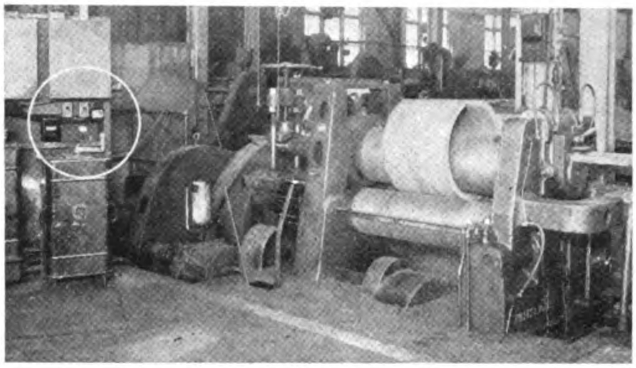
See the figure on the next page.

An arrangement of this type may be made exceedingly sensitive, depending on the initial air-gap setting. Assuming, for example, that the initial air-gap setting is 0.002 in., closing the gap by 0.001

*This lesson is reprinted from an article by H. P. Kuehni of the *General Electric Co.* whose permission was obtained for this purpose.

The meter calibration changes somewhat for different temperatures.

in. will produce approximately a 100 per cent reactance change and a correspondingly large bridge circuit output. While the sensitivity may be increased much further by simply reducing the initial air gap, practical limits are reached because of temperature expansions of the gage members and of the parts to be gaged. In general, reliable readings of one hundred-thousandth inch are obtainable; and under carefully controlled conditions armature displacements as small as one millionth inch may be read.

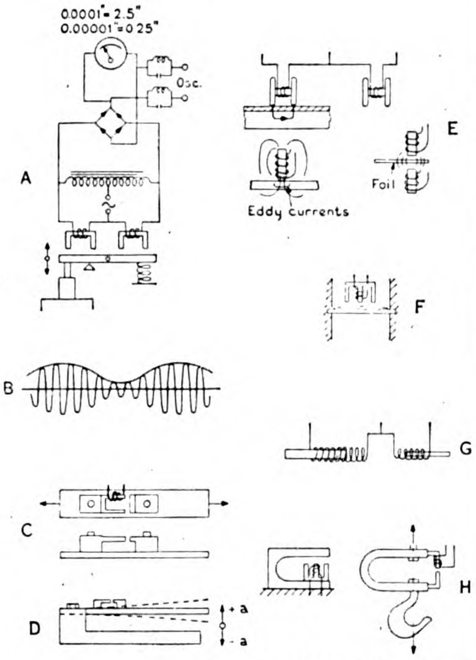


Courtesy "Radio News" Magazine

Figure 361. A bending roll machine equipped with electromagnetic strain gage as shown within the circle. The equipment is adjusted to give an alarm when the machine is overloaded.

TYPES AND APPLICATION. In the foregoing example, a reactance change was obtained by varying the air gap in a magnetic circuit. As far as the bridge circuit is concerned, it is immaterial how the coil reactance or impedance change comes about. For example, an impedance change may also be obtained by placing in the air gap, which is made large in this case, a sheet of conducting material.

In the figure are shown schematically some representative applications of the electromagnetic gage principle. In this illustration is shown how the principle is applied to comparator, thickness (air-gap and eddy-current types), displacement, pressure, strain, acceleration, and weight gages.



Courtesy General Electric Co.

Figure 362. Schematic representations of electric gage circuit applications. (A) one of a variety of electric gage bridge circuits. (B) a representation of the fundamental frequency employed and its modulation by variations in the quantity being measured. (A) and (C) to (H) are representations of several different applications of the electric gage; (A) comparator; (C) strain; (D) acceleration; (E) thickness; (F) pressure; (G) displacement; (H) weight.

When the quantity to be gaged varies, the alternating output voltage from the bridge circuit also varies accordingly. The fundamental bridge frequency, however, is retained except that it is modulated corresponding to the frequency of the variations. Slow variations can be followed by an indicating instrument, but more rapid variations require the use of a fast-responding recorder or an oscillograph. In order to reproduce the variations faithfully, there must be available a sufficient number of loops of the fundamental frequency for their reproduction. In general, it may be said that the frequency applied to the bridge circuit should be at least four times as high as the frequency of the variations which are to be recorded. Thus, with a bridge excitation of 60 cycles per second, good reproductions may be obtained of variations up to 15 cycles; and with a bridge excitation of 2,000 cycles, variations up to 500 cycles may be recorded.

In another type gage used for the measurement of strain, resistance elements are often used. These elements are cemented on the test members and the resistance of these elements changes slightly (a fraction of one per cent) under strain.

LESSON 45

Film-Thickness Gage

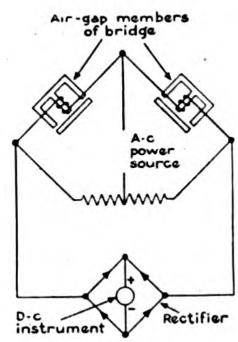
PURPOSE AND APPLICATION. A film-thickness gage will measure the thickness of vitreous enamel, lacquer, other similar non-magnetic coatings, and silver or copper plating on steel or iron base. Since the exploring element is only held in contact with the surface, no injury results to the coating. The gage may be used also for measuring the thickness of glass, paper, mica, zinc, tin, or other non-magnetic materials which are placed or coated on steel or iron. The measurements may be made on all types of surfaces provided the base is .007 of an inch or more in thickness and is of magnetic material. Extreme curvature of the surface to be tested is to be avoided. Correction charts are supplied for making measurements on high-carbon steel, alloy steel containing nickel or chromium, very thin sheets, or highly irregular and extremely curved surfaces.

Courtesy General Electric Co.
Figure 364. Film-thickness gage complete with probe.

Courtesy General Electric Co. and Ford Motor Co.
Figure 363. Measuring thickness of lacquer on an automobile body.

CIRCUIT AND OPERATION. The operation of this gage is based also on the principle of the Wheatstone bridge as shown in the figure in the margin. Two arms of the bridge are formed by the iron core reactors. These are balanced against each other to balance the bridge. One of these reactors is incorporated in the case of the gage, while the second reactor is inclosed in the exploring probe. Adjustment is carried out for *zero* thickness with the aid of the potentiometer while the probe is held directly against a bare magnetic material. The magnetic circuit of the reactor in the probe is completed through the magnetic material used as the base. Since the greater part of the reluctance (opposition to magnetic field) of this magnetic circuit is produced by the air gap or the non-magnetic material that separates the gage head or probe from the steel or iron, the indicating meter shows directly the thickness of the non-magnetic material.

The indicating unit is readily adjusted by placing a thickness standard between the gage head and a sheet of steel or iron, which should be of the same grade and thickness as the metal over which the non-magnetic material is placed or coated. The potentiometer controlled by the knob on the front panel is adjusted until the instrument needle indicates the same thickness as that of the standard that is being used.



The basic circuit of the *General Electric* film-thickness gage.

LESSON 46

In a recent magazine article, Mr. H. S. Kartsher, of the *Brush Development Co.*, defines surface irregularities in the following manner:

ROUGHNESS, created by the removal of metal from the surface by production methods such as turning, grinding, or lapping.

WAVE, is caused by chatter, non-rigidity of the machining elements, grinding wheel feed, or diamond marks.

TRUTH, is the degree of *flatness* in flat work or *roundness* in round work. It is the geometric quality of the surface, larger than the first two qualities described.

FLAWS, may be caused by handling, scratches from stray grains, etc.

PATTERN (also called *lay*), is an indication of the type of operation performed. A circumferential pattern is produced by the ordinary grinding operation.

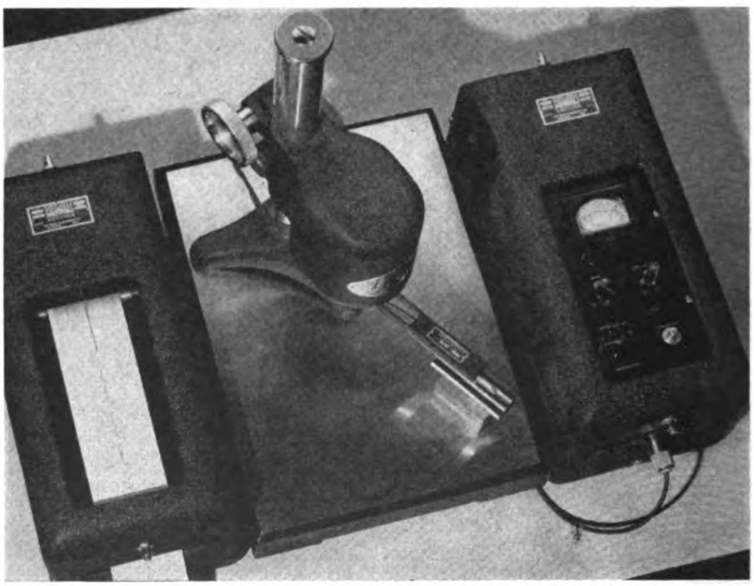
APPEARANCE, takes up the matter of polish, reflectivity, and sand blasting.

The analyzer described in this lesson is used primarily for inspection of *roughness* as defined above.

Surface Analyzer

Irregularity of Metal Surfaces. Metal surfaces may be finished to various degrees of smoothness and the irregularities present may be of different types. Surface irregularities in the form of waves or bumps are present in machined surfaces. These usually have wavelengths that are shorter than $\frac{1}{32}$ of an inch, and have peak-to-valley amplitudes in excess of one millionth of an inch (1 micro-inch). In order to meet rigid specifications and to quickly inspect metal surfaces in production, an electronic surface analyzer is employed. This unit employs an analyzer head, a calibrated amplifier, and a direct inking oscillograph which makes a permanent record.

Description of the Analyzer Head. The analyzer head consists principally of a calibrated crystal type pickup unit housed in a projecting arm, and the drive unit with its stand. The drive unit contains a 110 volt, 60 cycle A.C. synchronous motor which operates a cylindrical cam. This cam imparts a straight line reciprocating (up and back) motion to the pickup arm, about .060 inch long in each direction. This motion is accomplished at a uniform velocity and one complete cycle requires ten seconds.



Courtesy The Brush Development Co.

Figure 365. The units which make up a complete surface analyzer. The analyzer head is in the center, with the direct inking recorder at the left and the amplifier at the right.

The pickup arm is pivoted in conical bearings located in the drive unit. This arm is provided with a diamond tracer point having a spherical radius of .0005 inch, which can be used to measure the minute depth irregularities in metals as described above. This point is positioned by a spring and can be adjusted to give a pressure of .05 grams or less. (One pound equals about 454 grams.)

(*Continued on page* 364)

LESSON 47

Facsimile Equipment

Purpose and Results Obtained. The technique of transmitting printed material, drawings, and photographs by means of radio equipment, and to have this material reproduced directly on white paper is the method of facsimile. In order to transmit a view of a printed page or a picture, the object to be transmitted must be sub-divided into elementary areas by the scanning apparatus. This work can be carried out with the aid of a photo-cell and after suitable amplification the dots making up the object to be transmitted may be employed to modulate the carrier of a radio station.

At the receiving station, a suitable facsimile receiver may have its own radio apparatus or may be used in conjunction with a regular broadcast receiver. White paper comes off a roll at a fixed and synchronized speed and, in some units, carbon paper rides just above this white paper. For each dot to be formed, a single point of contact is established by the raised line of the helix on the surface of the roller and the movable bar above the paper and roller, see figure. The pressure is proportional to the *tone* of the corresponding element of the original material being transmitted. With proper synchronization, a complete document, copy of a telegram, a military map, or an entire newspaper (in condensed form) could be transmitted over a period of night hours.

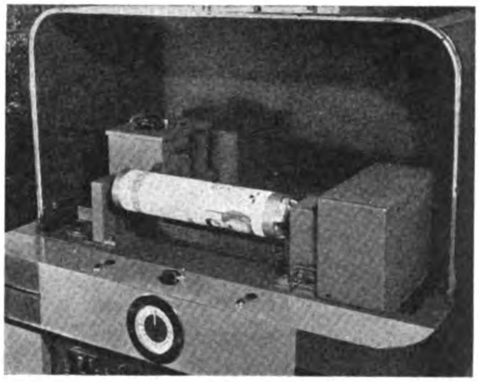
Scanning Equipment at the Transmitter. A unit of the most modern design will be described. The scanning equipment is housed in a metal cabinet and is complete in every detail. The operating power may be obtained from a regular power line and the output from the unit may be fed to a broadcast station by making a connection to a telephone line. The material to be transmitted is mounted on the subject-drum which rotates 75 r.p.m. being driven by a synchronous 60 cycle motor through a set of gears.

The incorporation of a clutch between the motor and the drum carrying the copy permits the changing of the copy without losing the relative frame position. The motor continues to run during this loading operation and a commutator on the spindle shaft supplies an artificial frame-line signal which is transmitted at the required intervals and keeps the recorders (at the receiving stations) in step.

During transmission the scanning head, which contains the optical system and the photo-cell and is mounted behind the subject drum, traverses slowly down the length of the copy. It is driven by a lead screw and suitable gearing from a separate motor and its rate of progress is such that 125 scanning lines are drawn per inch of drum length.

Facsimile Broadcast Receiver. Since there are always several facsimile recorders to every transmitter, even in experiment work, and there will be thousands, or even millions of facsimile recorder-receivers in the near future when facsimile broadcast transmission will be enlarged, you are primarily interested in such receivers.

Although facsimile equipment has found extensive use in military application and for news transmission, the big future lies in the use of this equipment in the homes for receiving directly *printed* newspapers.

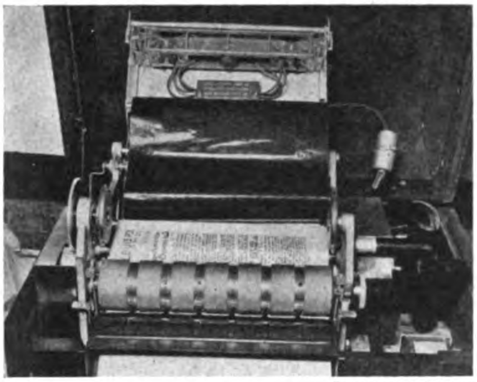


Courtesy of RCA

Figure 366. A view of the subject-drum and scanning apparatus of a facsimile unit.

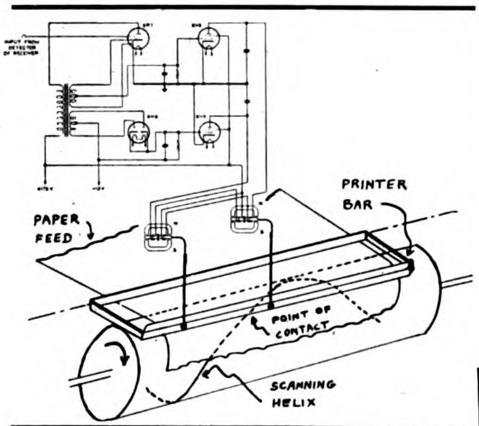
Refer to the illustration above.

FACSIMILE RECORDER



Courtesy of RCA

Figure 367. Inside view of the facsimile recorder. Ordinarily, the cover protects this machinery and the printed paper comes out through the slot in the cabinet.



The present day commercial facsimile receivers are complete self-contained machines. They include the needed radio receiver, time switch, and the facsimile unit; thus they require only the connection to an antenna and a source of power. While it is possible to use a regular good-quality broadcast radio for the receiver, certain advantages are offered by the separate receiver. According to the latest plans, the schedules are to be sent out over regular broadcast stations between midnight and six in the morning, a period when most radio channels are idle. The recorders are to be turned on and off by the time switch at the proper hours. If a regular radio is to be used, it has to be adjusted for the right station and connected to the time switch before the owner retires. This is too much to expect from an average person with many things to tax his memory. Also, a special radio chassis designed for facsimile reception can be made more efficient for the purpose on hand.

The facsimile recording machine is mounted in the upper section of the cabinet. The recording drum with the raised helical ridge on its surface rides below the white and carbon papers. The carbon paper is wound up after use on the core at the top; the white paper is fed out from the front of the cabinet by a cylinder like a typewriter roll. The printer bar is movable and presses against the carbon paper to leave an impression on the white paper. The motion of the printer bar is controlled by two electromagnetic drivers.

Whenever a signal for black is received, the printing bar pinches the carbon paper against the white at the point where its edge intersects the single turn raised helix; and, because of the rotation, this intersection point repeatedly scans across the page right in step with the traverse of the light spot across the original at the scanner. With complete synchronization, the dots will organize themselves into a facsimile of the original subject.

U-H-F OSCILLATORS

(*Continued from page* 324)

Klystron Oscillator. A klystron is a velocity-modulated tube which may be used for generating or amplifying extremely high frequencies, as high as 3,000 MC. A suitable emitter is incorporated in a vacuum tube made up of two cavity resonators. Positive potential is used to impart high velocity to the electrons. The action of the tube produces bunching of some electrons and, thereby, delivers energy to the second cavity resonator known as the *catcher*. Oscillations may be produced by feeding back some of this energy to the first cavity which creates the bunching action. Coaxial cable is used to conduct this energy back to the *buncher* and to the external radiator.

Magnetron Oscillator. The usual magnetron tube has a center filament and a cylindrical split-anode. Under ordinary conditions with a positive voltage applied to the anode (plate), the electrons emitted by the cathode-filament travel to the plate. The presence of a strong magnetic field at right angle to the normal path of electrons can be used to influence this path. Electrons can be made to describe half loops or travel in circles between the filament and anode. The electrical constants can be adjusted so that the time taken for the electrons to move from the cathode toward the anode and back is equal to the period of oscillations of the external ultra high frequency oscillatory circuit. In this manner, energy will be added to the oscillatory circuit at the right moments to sustain oscillation.

Magnetron oscillators are used for generating ultra-high frequencies, needed in Radar work.

CORRELATION OF TUBE TYPES FOR SUBSTITUTION

•

This correlation of Sylvania tube types is made available as a guide for simplifying tube substitution. In order to make the selection for substitution as large as possible two reference columns are given for each listed type—tubes having "Equivalent" characteristics and tubes having "Similar" characteristics.

EQUIVALENT TYPES—tubes listed as "Equivalent" are those which have electrical characteristics and circuit applications equivalent to the listed types.

SIMILAR TYPES—tubes listed as "Similar" are those which have electrical characteristics and circuit applications similar to the listed types.

It is not implied that tubes listed as "Equivalents" are interchangeable, however, many of them are directly interchangeable or interchangeable by a slight change in circuit constants. Such tubes are marked with an asterisk (*). Types not marked with an asterisk in the "Equivalent" column may be made interchangeable by changing the socket or filament rating.

The "Similar" tubes are not interchangeable unless marked with an asterisk, but as the circuit applications and characteristics are similar these types can be made to function as substitutes, thus giving a wide selection of tube types from which to choose.

When making any substitution changes it will be necessary to refer to the operating characteristics and basing diagrams shown in the Sylvania Technical Manual or Characteristic Sheet so that full benefit of the changes will be realized and no tube will be used in such a way that it will be abused.

In some cases realignment of tuned circuits may be necessary, particularly where capacitances differ. Also external shielding may be required, especially when replacing metal tubes with glass types.

This chart is a war time expedient to be consulted when exact replacements are not available

Type	Style	Service	Characteristics Equivalent To	Characteristics Similar To
0A4G	G	Rectifier	....	....
0Z4	Metal	Rectifier	0Z4G*	6X5GT/G
0Z4G	G	Rectifier	0Z4*	6X5GT/G
01A §	Glass	Amplifier	....	30
1A4P	Glass	R-F Amplifier	1A4T*	1D5GP
1A4T	Glass	R-F Amplifier	1A4P*	....
1A5G §	GT	Power Amplifier	1A5GT/G*	1C5GT,/G 1G5G
1A5GT §	GT	Power Amplifier	1A5GT/G*	1C5GT/G, 1G5G
1A5GT/G	GT	Power Amplifier	1A5G*, 1A5GT*	1C5GT/G, 1G5G
1A6	Glass	Pentagrid Converter	1D7G	1C6
1A7G §	G	Pentagrid Converter	1A7GT/G*	1C7G, 1D7G, 1A6
1A7GT §	GT	Pentagrid Converter	1A7GT/G*	1A6, 1C7G, 1D7G
1A7GT/G	GT	Pentagrid Converter	1A7G*, 1A7GT*	1A6, 1C7G, 1D7G
1B4P §	Glass	R-F Amplifier	1E5GP	32
1B5/25S	Glass	Duodiode Detector	1H6G	....
1B7G §	G	Pentagrid Converter	1B7GT/G*	1C6, 1C7G
1B7GT §	GT	Pentagrid Converter	1B7GT/G*	1C6, 1C7G
1B7GT/G	GT	Pentagrid Converter	1B7G*, 1B7GT*	....
1C5G §	G	Power Output Amp.	1C5GT/G*	1A5GT/G, 1G
1C5GT §	GT	Power Amplifier	1C5GT/G*	1A5GT/G, 1G
1C5GT/G	GT	Power Amplifier	1C5G*, 1C5GT*	1A5GT/G, 1G
1C6	Glass	Pentagrid Converter	1C7G	1A6
1C7G	G	Pentagrid Converter	1C6	1A6, 1A7GT/ 1D7G
1D5GP	G	R-F Amplifier	1A4P	1N5GT/G, 34
1D5GT	G	R-F Amplifier	1A4P	34
1D7G §	G	Pentagrid Converter	1A6	1A7GT/G, 1C 1C7G
1D8GT	GT	Diode Tri. Pent.	1LB4 and 1LH4	....

Type	Style	Service	Characteristics Equivalent To	Characteristics Similar To
4G§	G	Triode	1LE3	....
5GP§	G	R-F Amplifier	1B4P	32
7G§	G	Power Output Pent.	....	(Two 1F4's)
4	Glass	Power Output Pent.	1F5G	33, 1G5G, 1J5G
5G	G	Power Output Pent.	1F4	33, 1G5G, 1J5G
6	Glass	Duodiode Pentode	1F7G	1B5/25S, 1H6G
7G	G	Duodiode Pentode	1F6	1B5/25S, 1H6G
4G§	G	Triode	1G4GT/G*	30, 1H4G
4GT§	GT	Triode	1G4GT/G*	30, 1H4G
4GT/G	GT	Triode	1G4G*, 1G4GT*	30, 1H4G
5G§	G	Power Output Pent.	....	1F4, 1F5G
6G§	G	Power Amplifier	1G6GT/G*	19, 1J6G
6GT§	GT	Power Amplifier	1G6GT/G*	19, 1J6G
6GT/G	GT	Power Amplifier	1G6G*, 1G6GT*	19, 1J6G
4G	G	Amplifier	30	....
5G§	G	Diode Triode Amp.	1H5GT/G*	1B5/25S
5GT§	GT	Diode Triode	1H5GT/G*	1B5/25S
5GT/G	GT	Diode Triode	1H5G*, 1H5GT*	1B5/25S
6G	G	Duodiode Detector	1B5/25S	1F6
5G§	G	Power Output Pent.	....	1F4, 1F5G, 1G5G, 33
5G	G	Power Output Amp.	19♯	(Two 31's)
A4	Lock-In	Power-Amplifier	1A5GT/G	1C5GT/G
A6	Lock-In	Pentagrid Converter	1A7GT/G	1A6
B4	Lock-In	Power Amplifier	....	1T5GT
C5§	Lock-In	R-F Amplifier	1LN5*	1N5GT/G
C6	Lock-In	Pentagrid Converter	1LA6*, 1A7GT/G	1A6
D5	Lock-In	Diode Pentode	....	1S5
E3	Lock-In	Triode	1E4G	....
H4	Lock-In	Diode Triode	1H5GT/G	1B5/25S
N5	Lock-In	R-F Amplifier	1LC5*	1N5GT/G
5G§	G	R-F Amplifier	1N5GT/G*	1A4P, 1D5GP
5GT§	GT	R-F Amplifier	1N5GT/G*	1LN5, 1LC5
5GT/G	GT	R-F Amplifier	1N5G*, 1N5GT*	1LN5, 1LC5
6G§	G	Diode Pentode	....	....
5G§	G	R-F Amplifier	1P5GT/G*	1N5GT/G
5GT§	GT	R-F Amplifier	1P5GT/G*	1N5GT/G
5GT/G	GT	R-F Amplifier	1P5G*, 1P5GT*	1N5GT/G
Q5G§	G	Power Amplifier	1Q5GT/G*	1C5GT/G
Q5GT§	GT	Power Amplifier	1Q5GT/G*	1C5GT/G
Q5GT/G	GT	Power Amplifier	1Q5G*, 1Q5GT*	1C5GT/G
5	Miniature	Converter	....	1A6, 1A7GT/G
4	Miniature	Power Amplifier	....	1Q5GT/G, 1C5GT/G
5	Miniature	Diode Pentode	1LD5	....
4	Minature	R-F Amplifier	1N5GT/G, 1LN5	....
5GT	GT	Power Amplifier	....	1C5GT/G, 1LB4
/	Glass	Rectifier	....	12Z3
A3	Glass	Power Output Tri.	6A3♯, 6B4G♯	45
A4G	G	Gas Triode	....	2051
A5	Glass	Power Output Pent.	6F6G♯, 42♯	47
A6	Glass	Duodiode Detector	6Q7G♯, 75♯	....
A7, 2A7S§	Glass	Pentagrid Converter	6A7♯, 6A7S♯	....
37§, 2B7S§	Glass	Duodiode Pentode	6B7♯, 6B7S♯	....
E5§	Glass	Tuning Indicator	6E5♯	....
/4S§	Glass	Duodiode Detector	....	....
W3§	Glass	Rectifier	....	80
Z2/G84§	Glass	Rectifier	....	....
A8GT	GT	Diode Triode Pent.	1H5GT/G, and 1N5GT/G	....
LF4	Lock-In	Power Amplifier	3Q5GT/G	....
Q5G§	G	Power Amplifier	3Q5GT/G*	3LF4
Q5GT§	GT	Power Amplifier	3Q5GT/G*	3LF4
Q5GT/G	GT	Power Amplifier	3Q5G*, 3Q5GT*	3LF4
S4	Miniature	Power Amplifier	....	3Q5GT/G
T4§	Metal	Rectifier	5U4G*	5V4G*, 83V
U4G	G	Rectifier	5Z3, 5X4G	5T4
V4G	G	Rectifier	83V	5T4
W4§	Metal	Rectifier	5W4GT/G*	5Y3GT/G*, 5Z4, 80
W4G§	G	Rectifier	5W4GT/G*	5Y3GT/G*
W4GT§	GT	Rectifier	5W4GT/G*	5Y3GT/G*
W4GT/G	GT	Rectifier	5W4*, 5W4G*, 5W4GT*	5Y3GT/G*
X4G	G	Rectifier	5Z3, 5U4G	....
Y3G§	G	Rectifier	5Y3GT/G*	5Z4*
Y3GT§	GT	Rectifier	5Y3GT/G*, 80, 5Y4G	5Z4*
Y3GT/G	GT	Rectifier	5Y3G*, 5Y3GT*	5Z4*
Y4G§	G	Rectifier	5Y3GT/G*, 80	5Z4
Z3	Glass	Rectifier	5U4G, 5X4G	83

Type	Style	Service	Characteristics Equivalent To	Characteristics Similar To
5Z4	Metal	Rectifier	....	5Y3GT/G*, 5Y4G
6A3	Glass	Power Output Tri.	2A3♯, 6B4G	45
6A4/LA§	Glass	Power Output Pent.	....	41
6A5G§	G	Power Output Tri.	....	6A3, 6B4G*
6A6	Glass	Power Output Amp.	6N7, 6N7G, 53♯	....
6A7, 6A7S§	Glass	Pentagrid Converter	6A8†, 6A8G, 2A7♯, 2A7S♯	....
6A8	Metal	Pentagrid Converter	6A7†, 6A8G†*	6D8G
6A8G	G	Pentagrid Converter	6A7, 6A8†*	6D8G
6A8GT	GT	Pentagrid Converter	6A8*, 6A8G*	6A7
6AB5/6N5	Glass	Tuning Indicator	....	6E5
6AB7/1853	Metal	Pentode Amplifier	....	7H7, 7L7
6AC5G§	G	Power Amplifier	6AC5GT/G*	....
6AC5GT§	GT	Power Amplifier	6AC5GT/G*	....
6AC5GT/G	GT	Power Amplifier	6AC5G*, 6AC5GT*	....
6AC7/1852	Metal	Pentode Amplifier	....	7V7
6AD6G§	G	Tuning Indicator	6AF6G*	6E5
6AD7G	G	Triode Pentode	....	....
6AE5G§	G	Amplifier	6AE5GT/G*	....
6AE5GT§	GT	Amplifier	6AE5GT/G*	6J5GT/G
6AE5GT/G	GT	Amplifier	6AE5G*, 6AE5GT*	6J5GT/G
6AE6G§	G	Double Triode	....	....
6AE7GT§	GT	Twin Triode	....	....
6AF5G§	G	Amplifier	....	....
6AF6G§	G	Tuning Indicator	6AD6G*	....
6AG7	Metal	Pentode Amplifier	....	....
6B4G	G	Power Output Tri.	6A3, 2A3♯	6A5G, 45
6B5	Glass	Power Output Amp.	6N6G	42
6B7, 6B7S§	Glass	Duodiode Pentode	6B8G	6B8†
6B8	Metal	Duodiode Pentode	6B8G*	6B7
6B8G	G	Duodiode Pentode	6B8†	6B7
6C5	Metal	Triode Amplifier	6C5GT/G*	6J5GT/G, 6L5G, 6P5GT/G, 37, 76
6C5G§	G	Triode Amplifier	6C5†, 6C5GT/G*	6J5GT/G, 6L5G, 6P5GT/G, 37, 76
6C5GT§	GT	Triode Amplifier	6C5GT/G*	....
6C5GT/G	GT	Triode Amplifier	6C5*, 6C5G*, 6C5GT*	....
6C6	Glass	R-F Amplifier	6D7, 1221, 1223	6J7, 6J7G, 6W7G, 77*
6C7§	Glass	Duodiode Tri. Det.	6R7GT/G	75, 85
6C8G	G	Duotriode Amplifier	....	6F8G
6D6	Glass	R-F Amplifier	6E7, 6U7G	6K7, 6K7G, 6S7G 78*
6D7§	Glass	R-F Amplifier	6C6, 1221, 1223	6J7, 6J7G, 6W7G, 77
6D8G	G	Pentagrid Converter	....	6A7, 6A8, 6A8G
6E5	Glass	Tuning Indicator	2E5♯	6G5, 6T5, 6U5/6G5
6E6§	Glass	Power Output Amp.	....	....
6E7§	Glass	R-F Amplifier	6D6, 6U7G	6K7, 6K7G, 6S7G, 78
6F5	Metal	Triode Amplifier	6F5GT/G*	6K5GT/G
6F5G§	G	Triode Amplifier	6F5GT/G*	6K5GT/G
6F5GT§	GT	High Mu Triode	6F5GT/G*	6K5GT/G
6F5GT/G	GT	Triode Amplifier	6F5*, 6F5G*, 6F5GT*	6K5GT/G
6F6	Metal	Power Output Pent.	6F6G*	42, 2A5♯
6F6G	G	Power Output Pent.	6F6*	42, 2A5♯
6F7, 6F7S§	Glass	Triode Pent. Amp.	6P7G	....
6F8G	G	Twin Triode	6F8*, 7N7	6C8G (two 6J5GT/G's)
6G6G	G	Power Output Pent.	....	....
6H4GT	GT	Rectifier	....	....
6H6	Metal	Duodiode	6H6GT/G†*	7A6
6H6G§	G	Duodiode	6H6GT/G*	7A6
6H6GT§	GT	Double Diode	6H6GT/G*	7A6
6H6GT/G	GT	Double Diode	6H6*, 6H6G*, 6H6GT*	7A6
6J5	Metal	Triode Amplifier	6J5GT/G†*	6C5GT/G, 6L5G, 37, 76
6J5G§	G	Triode Amplifier	6J5GT/G*	6C5GT/G, 6L5G, 6P5GT/G, 37, 76
6J5GT§	GT	Triode	6C5GT/G*, 6J5GT/G*	....
6J5GT/G	GT	Triode	6J5*, 6J5G*, 6J5GT*	6C5GT/G*, 6P5GT/G
6J7	Metal	R-F Amplifier	6J7GT†*, 77†	6C6, 6W7G
6J7G	G	R-F Amplifier	6J7GT†*, 77	6C6, 6W7G
6J7GT	GT	Pentode Amplifier	6J7G*, 7C7	....
6J8G	G	Triode Hep. Con.	....	6K8
6K5G§	G	Triode Amplifier	6K5GT/G*	6F5GT/G
6K5GT§	GT	Amplifier	6K5GT/G*	6F5GT/G
6K5GT/G	GT	Amplifier	6K5G*, 6K5GT*	6F5GT/G
6K6G§	G	Power Output Pent.	6K6GT/G*, 41	6F6GT/G, 42

SYMBOLS: *—Indicates direct interchangeability. In some cases realignment of tuned circuits may be necessary particularly where capacitances differ.
♯—Equivalent Characteristics except for filament rating. †—Characteristics same as listed type except capacitances. §—Types no longer manufactured.

Type	Style	Service	Characteristics Equivalent To	Characteristics Similar To
6K6GT§	GT	Power Amplifier	6K6GT/G*, 41	6F6GT/G, 42
6K6GT/G	GT	Power Amplifier	6K6G*, 6K6GT*	6F6GT/G, 42
6K7	Metal	R-F Amplifier	6K7G†*, 78†	6D6, 6S7G, 6U7G
6K7G	G	R-F Amplifier	6K7†*, 78	6D6, 6S7G, 6U7G
6K7GT	GT	Pentode Amplifier	6K7G*, 77, 7A7	....
6K8	Metal	Triode Hex. Con.	6K8GT, 6K8G*	6J8G
6K8G	G	Triode Hex. Con.	6K8*, 6K8GT*	....
6K8GT	GT	Triode Hex. Con.	6K8G*	....
6L5G	G	Triode Amplifier	....	6C5GT/G, 6J5GT/G, 6P5GT/G, 76
6L6	Metal	Power Output Amp.	6L6G*	....
6L6G	G	Power Output Amp.	6L6*	....
6L7	Metal	Pentagrid Mixer	6L7G†*, 1612	....
6L7G	G	Pentagrid Mixer	6L7†*, 1612	....
6N6G	G	Power Output Amp.	6B5	6F6G, 42
6N7	Metal	Power Output Amp.	6A6, 6N7G*	53ƒ
6N7G§	G	Power Output Amp.	6A6, 6N7*	53ƒ
6P5G§	G	Triode Amplifier	56ƒ, 76, 6P5GT/G*	37, 6C5GT/G, 6J5GT/G, 6L5G
6P5GT§	GT	Triode Amplifier	76, 6P5GT/G*	37, 6C5GT/G, 6J5GT/G, 6L5G
6P5GT/G	GT	Triode Amplifier	6P5G*, 6P5GT*	37, 6C5GT/G, 6J5GT/G, 6L5G
6P7G§	G	Triode Pent. Amp.	6F7, 6F7S	....
6Q7	Metal	Duodiode Triode	6Q7G†*	6T7G, 75
6Q7G	G	Duodiode Triode	6Q7†*	6T7G, 75
6Q7GT	GT	Duodiode Triode	6Q7G*	6T7G, 75
6R7	Metal	Duodiode Triode	6R7GT/G†*	6V7G, 85
6R7G§	G	Duodiode Triode	6R7GT/G†*	6V7G, 85
6R7GT§	GT	Duodiode Triode	6R7GT/G*	6V7G, 85
6R7GT/G	GT	Duodiode Triode	6R7*, 6R7G*, 6R7GT*	6V7G, 85
6S7	Metal	Pentode Amplifier	6S7G*	....
6S7G§	G	Pentode Amplifier	6S7*	6D6, 6J7, 6K7G, 6U7G, 78
6SA7	Metal	Pentagrid Converter	6SA7GT/G*, 7Q7	....
6SA7GT§	GT	Pentagrid Converter	6SA7GT/G*, 7Q7	....
6SA7GT/G	GT	Pentagrid Converter	6SA7*, 6SA7GT*	....
6SC7	Metal	Twin Triode	7F7	....
6SD7GT	GT	Pentode Amplifier	....	7H7, 7L7
6SF5	Metal	High Mu Triode	6SF5GT*, 7B4	6F5GT/G
6SF5GT	GT	High Mu Triode	6SF5G*, 7B4	....
6SF7	Metal	Diode-Pentode	7E7	6B8G, 6B7
6SG7	Metal	R-F Pentode	7W7	....
6SH7	Metal	R-F Pentode	7W7	....
6SJ7	Metal	Pentode Amplifier	6SJ7GT*, 7C7	....
6SJ7GT	GT	Pentode Amplifier	6SJ7*, 7C7	....
6SK7	Metal	Pentode Amplifier	6SK7GT/G*, 7A7	....
6SK7GT§	GT	Pentode Amplifier	6SK7GT/G*, 7A7	....
6SK7GT/G	GT	Pentode Amplifier	6SK7*, 6SK7GT*	....
6SL7GT	GT	Duo-Triode	7F7	6SC7
6SN7GT	GT	Duo-Triode	7N7, 6F8G	Two 6J5GT/G's
6SQ7	Metal	Duodiode Triode	6SQ7GT/G*, 7B6	....
6SQ7GT§	GT	Duodiode Triode	6SQ7GT/G*, 7B6	....
6SQ7GT/G	GT	Duodiode Triode	6SQ7*, 6SQ7GT*	....
6SR7	Metal	Duodiode Triode	6R7GT/G, 7E6	....
6SS7	Metal	R-F Pentode	6SK7GT/G	7A7
6ST7	Metal	Duodiode Tri.	6SR7, 6R7GT	6SQ7GT/G
6T5§	Glass	Tuning Indicator	6U5/6G5*	6E5
6T7G§	G	Duodiode Tri. Amp.	....	6Q7, 6Q7G, 75
6U5/6G5	Glass	Tuning Indicator	6G5*, 6T5*	6E5
6U7G	G	R-F Amplifier	6D6, 6E7	6K7, 6K7G*, 6S7G
6V6	Metal	Power Output Amp.	6V6GT/G*	....
6V6G§	G	Power Output Amp.	6V6GT/G*	....
6V6GT§	GT	Power Amplifier	6V6GT/G*, 7C5	....
6V6GT/G	GT	Power Amplifier	6V6*, 6V6G*, 6V6GT*	....
6V7G§	G	Duodiode Triode	55ƒ, 85	6R7GT/G
6W7G	G	R-F Amplifier	....	6C6, 6J7, 6J7G, 77
6X5§	Metal	Rectifier	6X5GT/G*, 84	0Z4G
6X5G§	G	Rectifier	6X5GT/G*, 84	0Z4G
6X5GT§	GT	Rectifier	6X5GT/G* 84	0Z4G
6X5GT/G	GT	Rectifier	6X5*, 6X5G*, 6X5GT*	0Z4G
6Y5§	Glass	Rectifier	....	6X5GT/G, 84
6Y6G§	G	Power Output Amp.	....	....
6Y7G	G	Power Output Amp.	79	6Z7G
6Z5§	Glass	Rectifier	....	....
6ZY5G	G	Rectifier	....	....

Type	Style	Service	Characteristics Equivalent To	Characteristics Similar To
6Z7G	G	Power Output Amp.	....	6Y7G, 79
7A4	Lock-In	Triode	6J5GT/G	....
7A5	Lock-In	Power Amplifier	....	35A5, 7B5
7A6	Lock-In	Duodiode	6H6GT/G	....
7A7	Lock-In	Pentode Amplifier	6SK7GT/G	....
7A8	Lock-In	Octode Converter	6A8GT	....
7B4	Lock-In	Triode	6F5GT/G	....
7B5	Lock In	Power Amplifier	6K6GT/G, 41	....
7B6	Lock-In	Duodiode Triode	75, 6SQ7GT/G	....
7B7	Lock-In	Pentode Amplifier	7A7*, 78	6SK7GT/G
7B8	Lock-In	Pentagrid Converter	7A8*, 6A8GT	....
7C5	Lock-In	Power Amplifier	6V6GT/G	....
7C6	Lock-In	Duodiode Triode	7B6*, 6SQ7GT/G	....
7C7	Lock-In	Pentode Amplifier	6SJ7GT	....
7E6	Lock-In	Duodiode Triode	6SR7	....
7E7	Lock-In	Duodiode Pentode	6B8G	....
7F7	Lock-In	Twin Triode	6SC7	....
7G7/1232	Lock-In	Pentode Amplifier	....	7V7
7H7	Lock-In	Pentode Amplifier	....	7L7
7J7	Lock-In	Triode Hep. Con.	6J8G	....
7L7	Lock-In	Pentode Amplifier	....	7H7
7N7	Lock-In	Twin Triode	6F8G	....
7Q7	Lock-In	Pentagrid Converter	6SA7GT/G	....
7S7	Lock-In	Triode Hep. Con.	....	7J7
7V7	Lock-In	Pentode Amplifier	7W7*	....
7W7	Lock-In	Pentode Amplifier	7V7*	....
7Y4	Lock-In	Rectifier	6X5GT/G	....
7Z4	Lock-In	Rectifier	....	7Y4
10	Glass	Power Output Tri.	210T*	50
12A	Glass	Power Output Tri.	....	01A, 71A
12A5§	Glass	Power Output Pent.	....	....
12A7	Glass	Rectifier & Amplifier	....	25A7GT/G
12A8G§	G	Pentagrid Converter	12A8GT/G*	....
12A8GT§	GT	Pentagrid Converter	12A8GT/G*	....
12A8GT/G	GT	Pentagrid Converter	12A8G*, 12A8GT*	....
12B8GT	GT	Triode-Pent.	....	....
12C8	Metal	Duodiode Pentode	6B8 (Pentode Section)	....
12F5GT	GT	High Mu Triode	6F5GT/G	....
12J5GT	GT	Triode	6J5GT/G	....
12J7GT§	GT	Pentode Amplifier	12J7GT/G*	....
12J7GT/G	GT	Pentode Amplifier	12J7GT*	....
12K7G§	G	Pentode Amplifier	6K7G, 12K7GT/G*	....
12K7GT§	GT	Pentode Amplifier	6K7G, 12K7GT/G*	....
12K7GT/G	GT	Pentode Amplifier	12K7G*, 12K7GT*	....
12K8	Metal	Tri-Hexode Con.	6K8ƒ	....
12Q7G§	G	Duo-Diode Triode	12Q7GT/G*	6Q7G
12Q7GT§	GT	Duodiode Triode	12Q7GT/G*	6Q7GT
12Q7GT/G	GT	Duodiode Triode	12Q7G*, 12Q7GT*	6Q7GT
12SA7	Metal	Pentagrid Converter	12SA7GT/G*	6SA7
12SA7GT§	GT	Pentagrid Converter	12SA7GT/G*	6SA7GT
12SA7GT/G	GT	Pentagrid Converter	12SA7*, 12SA7GT*	6SA7GT
12SC7	Metal	Twin-Triode Amp.	....	6SC7, 7F7
12SF5	Metal	High Mu Triode	12F5GT, 12SF5GT*	....
12SF5GT	GT	High Mu Triode	12F5GT, 12SF5G*	....
12SF7	Metal	Diode-Pentode	7E7	6B8G, 6B7
12SG7	Metal	R-F Pentode	14W7	....
12SH7	Metal	R-F Pentode	14W7	....
12SJ7	Metal	R-F Amplifier	12SJ7GT*	6SJ7GT
12SJ7GT	GT	R-F Amplifier	12SJ7*	6SJ7GT
12SK7	Metal	R-F Amplifier	12SK7GT/G*	6SK7GT/G
12SK7GT§	GT	R-F Amplifier	12SK7GT/G*	6SK7GT/G
12SK7GT/G	GT	R-F Amplifier	12SK7*, 12SK7GT*	6SK7GT/G
12SL7GT	GT	Duotriode	14F7	....
12SN7GT	GT	Duotriode	14N7	Two 12J5GT's
12SQ7	Metal	Duodiode Triode	12SQ7GT/G*	6SQ7GT/G
12SQ7GT§	GT	Duodiode Triode	12SQ7GT/G*	6SQ7GT/G
12SQ7GT/G	GT	Duodiode Triode	12SQ7*, 12SQ7GT*	6SQ7GT/G
12SR7	Metal	Duodiode Triode	....	6SR7GT
12Z3	Glass	Rectifier	....	1V
14A4§	Lock-In	Triode Amplifier	7A4	6J5GT/G
14A7/12B7	Lock-In	Pentode Amplifier	7A7	6SK7GT/G
14B6§	Lock-In	Duodiode Triode	7B6	6SQ7GT/G
14B8§	Lock-In	Pentagrid Converter	7B8	6A8GT
14C5§	Lock-In	Power Amplifier	7C5	6V6GT/G
14C7	Lock-In	Pentode Amplifier	7C7	6SJ7GT
14E6§	Lock-In	Duodiode Triode	7E6	6SR7GT
14F7§	Lock-In	Twin Triode Amp.	7F7	6SL7GT

SYMBOLS: *—Indicates direct interchangeability. In some cases realignment of tuned circuits may be necessary particularly where capacitances differ.
ƒ—Equivalent Characteristics except for filament rating. †—Characteristics same as listed type except capacitances. §—Types no longer manufactured.

Type	Style	Service	Characteristics Equivalent To	Characteristics Similar To
14H7	Lock-In	Pentode Amplifier	7H7	....
14J7	Lock-In	Triode Hex. Con.	7J7	6J8G
14N7§	Lock-In	Twin Triode	7N7	6F8G
14Q7	Lock-In	Pentagrid Converter	7Q7	6SA7GT/G
14S7	Lock-In	Triode Hex. Con.	7S7	6J8G
14W7	Lock-In	Pentode Amplifier	7W7	....
14Y4§	Lock-In	Rectifier	7Y4	6X5GT/G
15§	Glass	R-F Pentode	....	24A
18§	Glass	Power Output Amp.	....	2A5, 42
19	Glass	Power Output Amp.	1J6G‡	(Two 31's)
20§	Glass	Power Output Amp.	....	X99
22§	Glass	R-F Amplifier	....	1B4P, 32
24A, 24S§	Glass	R-F Amplifier	....	35/51, 35S/51S
25A6§	Metal	Power Output Amp.	25A6GT/G*, 43	....
25A6G§	G	Power Output Amp.	25A6GT/G*, 43	....
25A6GT§	GT	Pentode Amplifier	25A6GT/G*, 43	....
25A6GT/G	GT	Pentode Amplifier	25A6*, 25A6G*, 25A6GT*	....
25A7G§	G	Rectifier & Amplifier	25A7GT/G*	12A7
25A7GT§	GT	Pentode-Rectifier	25A7GT/G*	....
25A7GT/G	GT	Pentode-Rectifier	25A7G*, 25A7GT*	....
25AC5G§	G	Power Triode	25AC5GT/G*	....
25AC5GT§	GT	Power Triode	25AC5GT/G*	....
25AC5GT/G	GT	Power Triode	25AC5G*, 25AC5GT*	....
25B5§	Glass	Power Amplifier	25N6G	....
25B6G§	G	Power Output Amp.	....	25A6G, 43
25B8GT§	GT	Pentode Triode	....	....
25C6G	G	Power Amplifier	6Y6G	....
25L6§	Metal	Power Output Amp.	25L6GT/G*	....
25L6G§	G	Power Output Amp.	25L6GT/G*	....
25L6GT§	GT	Power Amplifier	25L6GT/G*	....
25L6GT/G	GT	Power Amplifier	25L6*, 25L6G*, 25L6GT*	....
25Y5§	Glass	Rectifier	25Z5	....
25Z5	Glass	Rectifier	25Z6GT/G	....
25Z6	Metal	Rectifier	25Z3, 25Z6GT/G*	....
25Z6G§	G	Rectifier	25Z5, 25Z6GT/G*	....
25Z6GT§	GT	Rectifier	25Z5, 25Z6GT/G*	....
25Z6GT/G	GT	Rectifier	25Z6*, 25Z6G*, 25Z6GT*	....
26	Glass	Amplifier	....	....
27, 27S§	Glass	Amplifier	....	56*, 56S
30	Glass	Amplifier	1H4G	....
31§	Glass	Power Output Amp.	....	....
32	Glass	R-F Amplifier	....	1A4T, 1D5GT
32L7GT	GT	Tetrode, Rectifier	....	70L7GT
33	Glass	Power Output Amp.	....	1F4, 1F5G, 1G5G, 1J5G
34	Glass	R-F Amplifier	....	1D5GT, 1A4P, 1A4T, 1D5GP, 1N5GT/G
35/51	Glass	R-F Amplifier	35S, 51S	24A
35S/51S§	Glass	R-F Amplifier	35/51	24S
35A5	Lock-In	Power Amplifier	35L6GT/G	....
35L6G§	G	Power Amplifier	35L6GT/G*	25L6GT/G
35L6GT§	GT	Power Amplifier	35L6GT/G*	25L6GT/G
35L6GT/G	GT	Power Amplifier	35L6G*, 35L6GT*	25L6GT/G 50L6GT
35Y4	Lock-In	Rectifier	35Z5GT/G	....
35Z3	Lock-In	Rectifier	35Z4GT	....
35Z4GT	GT	Rectifier	35Z3	....
35Z5G§	G	Rectifier	35Z5GT/G*, 35Y4	....
35Z5GT§	GT	Rectifier	35Z5GT/G*, 35Y4	....
35Z5GT/G	GT	Rectifier	35Z5G*, 35Z5GT*	....
36	Glass	R-F Amplifier	....	6C6, 6J7
37	Glass	Triode Amplifier	....	6C5GT/G, 6J5GT/G, 6P5GT/G, 76*
38	Glass	Power Output Amp.	....	6K6GT/G, 41
39/44	Glass	R-F Amplifier	....	6D6, 6K7, 6K7G, 6S7G, 78
40§	Glass	Amplifier	....	....
40Z5/45Z5GT	GT	Rectifier	35Z5GT/G	....

Type	Style	Service	Characteristics Equivalent To	Characteristics Similar To
41	Glass	Power Output Pent.	6K6G	38, 42
42	Glass	Power Output Pent.	2A5‡, 6F6G	6F6
43	Glass	Power Output Pent.	25A6GT/G	48
45	Glass	Power Output Tri.	....	2A3
46	Glass	Power Output Amp.	....	....
47	Glass	Power Output Pent.	....	2A5
48§	Glass	Power Output Tet.	....	43
49§	Glass	Power Output Tet.	....	....
50	Glass	Power Output Tri.	....	10
50A5	Lock-In	Power Amplifier	50L6GT	....
50C6G§	G	Power Amplifier	....	25C6G
50L6GT	GT	Power Amplifier	....	25L6GT/G 35L6GT/G
50Y6G§	G	Rectifier	50Y6GT/G*	35Y4
50Y6GT§	GT	Rectifier	50Y6GT/G*	35Y4
50Y6GT/G	GT	Rectifier	50Y6G*, 50Y6GT*	35Y4
50Z7G§	G	Rectifier	....	....
53	Glass	Power Output Amp.	6A6‡, 6N7‡, 6N7G‡	....
55§, 55S§	Glass	Duodiode Triode	6V7G‡, 85‡	....
56, 56S§	Glass	Triode Amplifier	76‡	27, 27S
56AS§	Glass	Triode Amplifier	76‡	....
57, 57S§	Glass	R-F Amplifier	6C6‡	77
57AS§	Glass	R-F Amplifier	6C6‡	....
58, 58S§	Glass	R-F Amplifier	6D6‡, 6E7‡, 6U7G‡	....
58AS§	Glass	R-F Amplifier	6D7‡, 6E7‡, 6U7G‡	78
59	Glass	Power Output Amp.	....	....
70A7GT	GT	Rect. Pentode	....	70L7GT
70L7GT	GT	Tetrode, Rectifier	32L7GT	....
71A	Glass	Power Output Tri.	....	12A
75, 75S	Glass	Duodiode Triode	2A6‡	6Q7, 6Q7G, 6T7G
76	Glass	Triode Amplifier	6P5GT/G, 56‡	6L5G, 6C5GT/G 6J5GT/G, 37*
77	Glass	R-F Amplifier	6J7†, 6J7G	6C6*, 6W7G
78	Glass	R-F Amplifier	6K7†, 6K7G	6D6*, 6S7G
79	Glass	Power Output Amp.	6Y7G	....
80	Glass	Rectifier	5Y3GT/G, 5Y4G	....
81	Glass	Rectifier	....	....
82	Glass	Rectifier	....	....
83	Glass	Rectifier	....	83V, 5U4G, 5X4G, 5Z3, 5Z4G
83V	Glass	Rectifier	5Z4G	83
84/6Z4	Glass	Rectifier	6X5GT/G	....
85	Glass	Duodiode Triode	6V7G, 55‡	6R7GT/G
85AS§	Glass	Duodiode Triode	....	6R7GT/G, 85
89§	Glass	Power Output Amp.	....	....
V99§	Glass	Triode Amplifier	....	X99, 30‡
X99§	Glass	Triode Amplifier	....	V99, 20, 30‡
182B/482B§	Glass	Power Output Amp.	....	183/483*, 71A
183/483§	Glass	Power Output Amp.	....	182B/482B*, 71A
117L7GT§	GT	Tetrode, Rectifier	117L7/M7GT*	32L7GT, 70L7GT
117M7GT§	GT	Tetrode, Rectifier	117L7/M7GT*	32L7GT, 70L7GT
117L7/M7GT	GT	Tetrode, Rectifier	117L7GT*, 117M7GT*	32L7GT, 70L7GT
117N7GT	GT	Tetrode, Rectifier	....	32L7GT, 70L7GT
117P7GT	GT	Rect. Pentode	....	117L7/M7GT
117Z6G§	G	Rectifier	117Z6GT/G*	....
117Z6GT§	GT	Rectifier	117Z6GT/G*	....
117Z6GT/G	GT	Rectifier	117Z6G*, 117Z6GT*	....
210-T	Glass	Power Output Amp.	10*	....
485§	Glass	Triode Amplifier	....	27
864	Glass	Triode Amplifier	....	....
1221	Glass	Non-mic. Amplifier	1223, 6C6	6J7, 6J7G, 6W7G, 77
1223	G	Non-mic. Amplifier	1221, 6C6	6J7, 6J7G, 6W7G, 77
1231	Special	Triple Grid Amp.	....	....
1612	Metal	Non-mic. Amplifier	6L7, 6L7G‡	....
2051	G	Gas Tetrode	....	2A4G
XXD	Lock-In	Twin Triode	14AF7*	14N7
XXFM	Lock-In	Duodiode Triode	....	....
XXL	Lock-In	Triode	....	7A4

SYMBOLS: *—Indicates direct interchangeability. In some cases realignment of tuned circuits may be necessary particularly where capacitances differ.
‡—Equivalent Characteristics except for filament rating. †—Characteristics same as listed type except capacitances. §—Types no longer manufactured.

SYLVANIA ELECTRIC PRODUCTS INC. EMPORIUM, PENNA.

10M-8-26-43

LESSON 48

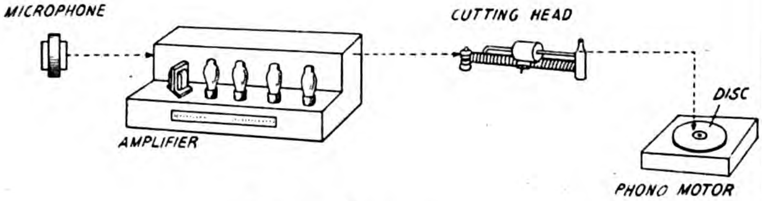
Recording Equipment

UNITS EMPLOYED TO MAKE UP A RECORDING SYSTEM. All modern recording systems include a suitable turn-table, recording head and arm, playback pickup, amplifier, and associated microphone and loudspeaker. Any of the sources of input discussed in connection with public address systems may be used with the recording amplifier. The output of the amplifier (about 5 to 10 watt size) is connected to the recording head. Many of the recording heads use a crystal element and are of the high impedance type. All of the older models and many modern units are of the magnetic type and these heads have various impedances. Very often, magnetic recording heads are supplied with an impedance of 4, or 8, or perhaps 500 ohms. Recording heads, as voice coils, must be properly matched to the audio amplifier output impedance and, further, must not carry any D.C.

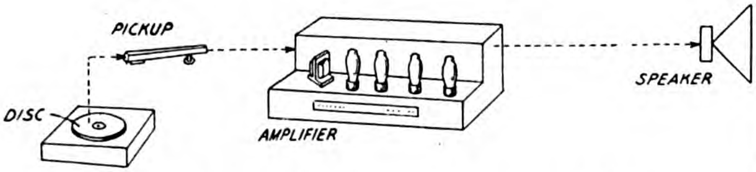
The turn-table motor must be strong enough to keep constant speed while turning a disc which is being *cut*. This motor must also turn a feed-screw mechanism having its gears engaged to move the recording head and the recording needle upon the disc in regularly spaced grooves. Rim-drive is used in most modern units, but constant speed electric motors are also directly coupled to the shaft of the revolving disc drive.

The play-back pickups are of the standard types described in connection with record players. Crystal types predominate.

PRINCIPLES OF RECORDING. The entire process of recording is based on a few simple principles of electrical, acoustical, and me-



The recording process.



The play-back arrangement. Phono motor is at left.

Figure 368. A picture illustration of the equipment involved in making records and for play-back purposes. Usually, this equipment is placed in a single cabinet and is connected for easy switch over to the play-back function.

A volume level indicator is essential for best results.

The recording head is used to convert audio frequency electrical energy to corresponding mechanical energy which causes the cutting needle to move from side to side at the audio rate.

Constant speed is needed to assure faithful reproduction when the record is rotated at the same speed for play-back purposes.

Observe what equipment is used for recording and also for play-back purposes.

HOW RECORDINGS ARE MADE

For example, a radio receiver may be used to deliver *sound* in electrical form.

The discs have paper, aluminum, steel, or glass base material with a coating of a plastic compound.

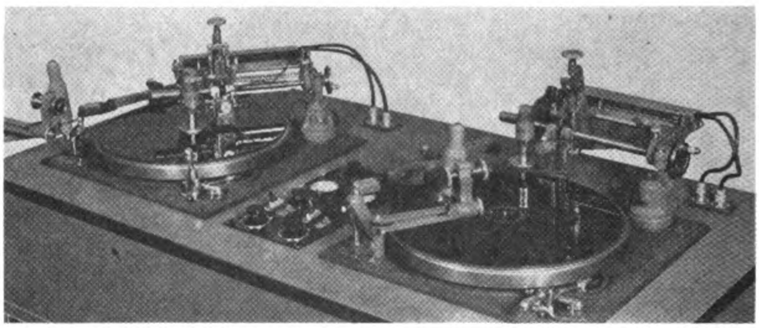
Follow this explanation by referring to the illustration on the previous page.

chanical sciences. Briefly, the sound, be it conversation, music, or singing, is delivered in electrical form or changed from sound energy to electrical energy. A crystal microphone is most often used for this purpose. The resulting electrical audio frequency energy is amplified by a suitable amplifier and the power is delivered to the cutting head.

As the disc upon which the *record* is to be made revolves, the cutting head cuts a groove and, at the same time, the needle of the cutter moves from side to side responding to the electrical equivalent of the original sound characteristics. In this manner, a record of the sound is made on the disc.

The entire process may be summarized briefly in terms of the stages through which the sound passes. First, the microphone changes the acoustical energy of the sound to electrical energy. This weak electrical energy is fed into the amplifier provided where it is increased to an intensity needed to operate the recording head. The recording head then changes this electrical energy to mechanical energy which is utilized to cut the disc.

In order to reproduce the recorded sound, the process is simply reversed. A pickup arm is used to convert the recorded sound back to electrical energy. This electrical signal, in turn, is fed to the input of the same (or different) amplifier. The pickup serves as the source of input to the amplifier, while a loudspeaker is connected to the output of the amplifier and changes the increased electrical energy back to sound. This process is also illustrated.



Courtesy Presto Recording Corp.

Figure 369. An illustration of a dual type turn-table used for continuous professional recording.

An automatic record changer permits the playing of several records in a selected order.

Home Recorders. Usually, a home recorder is a combination radio receiver, record player (at times with an automatic changer), and a recorder. The inclusion of a microphone also permits the use of the equipment as a small public address system. When in use as a radio set, the change-over switch on most models disconnects the microphone pre-amplifier, recording head, and phono pickup. For recording, the R.F. and I.F. sections are made inoperative and the mike pre-amplifier is connected to the audio input stage. The speaker (for this purpose) is disconnected, or silenced, or operated at reduced volume, and the recording head is connected to the output. A visual indicator, such as a meter, tuning eye, or neon tube, helps in adjusting for the correct volume level. For *off the air* recording, the R.F. section is left in operation to receive the wanted program while the mike channel is shut off.

For playback of the home made discs or any other records, we have another position of the change-over switch. Now, the pickup is connected to the audio input and the loudspeaker to the output. The R.F. and I.F. sections of the receiver are not used.

A complete manual of service notes on recorders, record players, and automatic changers, may be obtained from the publishers or your book dealer for $1.50.

LESSON 49

Inter-Communicators

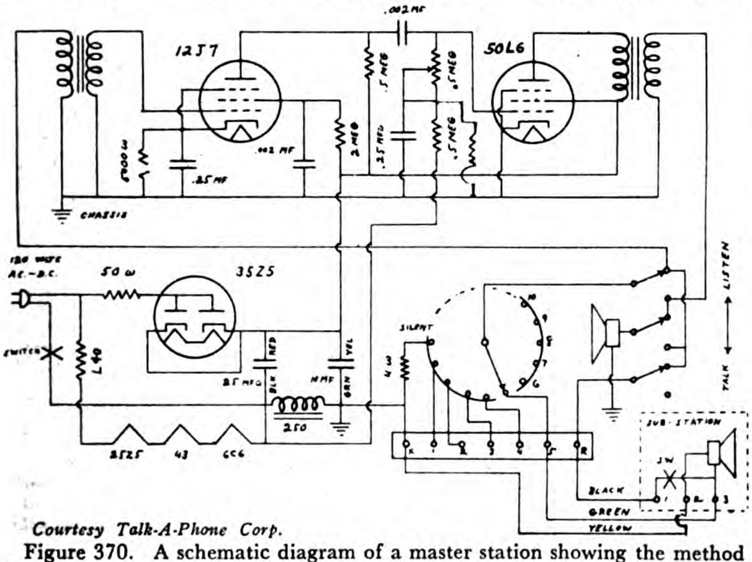
PURPOSE AND APPLICATION. Inter-communicators permit direct conversation between two or more remote points and employ audio amplifiers which use electronic tubes. Extensive use is made of inter-communicators on bombers and naval vessels. Here, quick direct two-point conversation permits exchange of vital information at an instants notice. In offices and factories, inter-communication systems supplement the telephone, reduce the burden at the switchboard, and eliminate delays and errors caused by the telephone operator. On a moments notice, the manager can ask the shipping clerk about a certain order, a Mr. Brown can be *paged* anywhere in the building, or the president and the manager can have a private conference with the aid of an inter-communication system.

Present day inter-communicators employ wires for connecting the outlying stations. It is possible, of course, to use radio transmission between stations, and one such system was popular some years back.

BASIC INTER-COMMUNICATION PRINCIPLES. When someone, perhaps 20 years ago, placed the loudspeaker some distance away from the audio amplifier and microphone, the first inter-communicator was born. The loudspeaker could be located in a room different from the one containing the amplifier and *mike.* By using a second system and placing the equipment *in reverse* to the first system, a two way conversation could be carried on. If both systems were left in the operating position, a loud howl would develop because of the electro-acoustic feedback. Means, therefore, were provided for breaking the circuit of each system at some point. The individuals using the equipment controlled these switches as the conversation shifted up and back between the two points.

The volume level of the sound produced by any one speaker, should be controllable at that location.

The realization that a magnetic or a P.M. speaker could serve as a microphone for voice frequencies made a great change in the design of inter-communicators. Assume you have a simple audio amplifier (see the schematic) incorporating a suitable input transformer to match the P.M. voice coil impedance to the *grid* and another transformer in the output to match the 50L6 tube to the



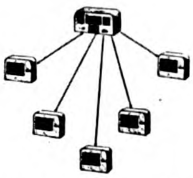
Courtesy Talk-A-Phone Corp.

Figure 370. A schematic diagram of a master station showing the method for connecting one sub-station to the unit.

Analyze the action of this circuit in detail. Study the effects of changing the position of the *talk-listen* switch.

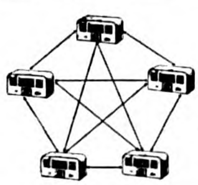
TYPES OF SYSTEMS

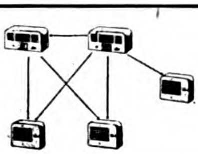
An ordinary loudspeaker does not make a good *microphone,* but by using special units good results can be obtained with voice frequencies.



Diagrammatical illustration which shows how a single master is connected to several sub-stations.

Distortion results because of phase shift in long lines. Considerable power is lost in extra long connecting cables.





same type of speaker. Also, assume you have two identical P.M. speakers. Call these speakers No. 1, and No. 2. By connecting one speaker to the input of the amplifier, and the other speaker to the output, conversation may proceed from No. 1 *speaker* (used as a mike, at this time) to No. 2 speaker. The No. 1 *speaker* may be in one room with the amplifier, while No. 2 speaker is connected with a long cable and is placed in another room. By employing a suitable switch, the connections of speaker No. 1, and speaker No. 2, could be reversed. Conversation can now originate at *speaker* No. 2 (used as a mike, now), and reproduced from speaker No. 1. The physical position (placement) of the speakers may remain the same. The controlling switch for the speaker-connections is included in the cabinet of the amplifier.

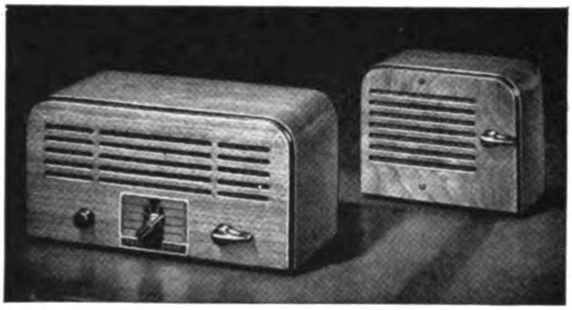


Figure 371. An illustration of a *Talk-A-Phone* intercommunicator showing the master and one sub-station.

Master Selective System. The natural outgrowth from the basic system described, is the *master selective* system. One amplifier unit with its speaker is still used at one location, but instead of one speaker at some other single point, several speakers are used and each is located at a different desk, or room, or station. In the commercial units, facilities are provided for ten such sub-stations, but any number less than ten can be used. The *Talk-A-Phone* KR-40 system permits private two-way communication between the amplifier (known as Master) station and any of the sub-stations. The master station can call all sub-stations simultaneously, if need for this operation arises. The sub-stations can answer and call the master station, but cannot call one another. It is possible to place the units as far as 3,000 feet apart from each other, but shorter distances are recommended. The person operating the master unit, of course, must control the *talk-listen* switch.

Super-Selective System. A complete system may be made up of master stations only to permit great freedom and versatility of operation. For example, in a system made up of ten such master stations five two-way private conversations can be held simultaneously without interference or cross-talk. Each station can call any other regardless of whether the station being called has the power "on" or not.

Combination Systems. It is possible to combine master stations, sub-stations, and special booster units to serve special requirements. You can readily understand that certain applications may require the master stations to have facilities to call any other master or any sub-station, but the sub-station may not require to originate the calls. Headphones may be incorporated for privacy of conversation. A booster unit is a high power amplifier which is used in connection with a sub-station for louder reproduction and paging.

LESSON 50

Sound-Level Meter

Purpose and Results Obtained. A sound-level meter is used to determine the intensity of sound in certain localities or produced by specific devices. With certain modifications, the same unit may be used to measure vibration of machinery and point to possible improvements in design. In ordinary application, a crystal microphone serves as the pickup and is connected to a portable, specially designed audio amplifier. The sound intensity is indicated on a calibrated decibel meter, but headphones, an oscilloscope, or a recording instrument may also be connected. The results obtained may be made to conform to the sensation-response characteristics of the human ear, or to give equal response to all frequencies. Since the human ear has somewhat different response to sound of different intensity levels, two corrective networks are provided; one for sound levels closest to 40 decibels, and another for very loud sounds around 70 decibels. The sound-level meter is calibrated directly in decibels above the standard reference level of 10^{-16} watts per centimeter. The range of such instruments may be from 24 to 130 decibels, which is sufficient for measuring all sounds commonly encountered — from those scarcely audible to sounds that are painful to the ear.

Circuit Details. Essentially, the sound-level meter of the usual type consists of a battery operated high gain audio amplifier capable of substantially uniform amplification throughout the frequency range of 50 to 8,000 cycles per second. Low drain battery tubes are employed and the entire unit with the batteries is housed in a convenient carrying case. The microphone is mounted on an extended arm so that it will not be affected by reflections of sound from the carrying case.

The sound-level meter may be calibrated with the aid of a mouth-blown whistle which is supplied with the unit. This whistle generates a tone of approximately 1,500 cycles of a definite intensity and is easily and quickly applied to the microphone for calibration adjustment.

Application Methods. For ordinary measurements, since the microphone is non-directional, it is only necessary to place or hold the unit in the location where the measurement is to be made. The microphone may be mounted on a separate stand, if the application requires this action, and connected to the sound-level meter with a suitable shielded cable.

Sound level measurements may be made to determine if a room is too noisy for certain types of work, the effects of acoustical treatment, or the best design for reduction of the noise level. Sound level and vibration measurements are used in industry for improving many devices such as pumps, fans, refrigerators, etc. The reduction of noise and vibration not only reduces the noise level at the place of the installation, but also increases the life of the equipment.

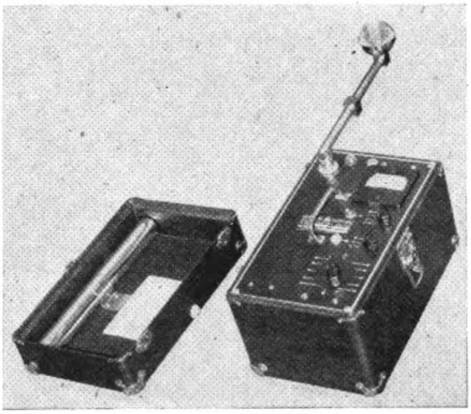


Figure 372. An illustration of a *General Electric* sound-level meter showing the extending microphone support. The calibrating unit is inside of the case cover.

Courtesy General Electric Co.

Figure 373. A sound-level meter being used to measure airplane-cabin noise.

LESSON 51

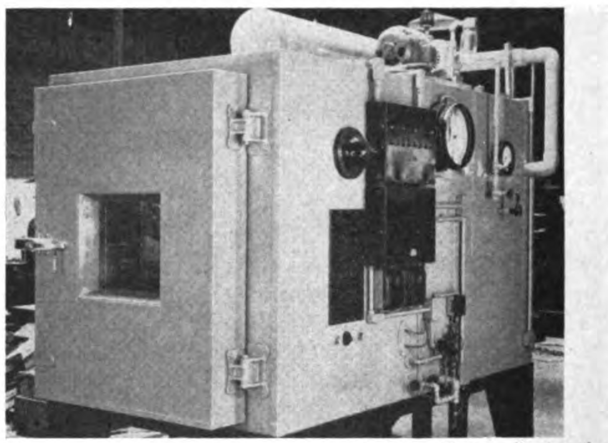
Test Cabinets

All or any of these factors may be made variable.

Purpose of Test Chambers. Test cabinets are used to provide any required constant or variable temperature, with various degrees of humidity, and under atmospheric pressures varying from stratosphere conditions to pressure of several atmospheres. Usually, these cabinets are custom made to specific requirements and the conditions needed for the application are obtainable. With the use of radio equipment under adverse conditions, the Army, Navy, and other government purchasing agencies have acted wisely in specifying tests which can be used to determine the suitability of the equipment for the function intended and prevent later failure due to the action of extreme temperature, humidity, or pressure. Test chambers are used extensively in designing and production testing of radio equipment intended to serve on board of aircraft or for military purposes in localities with adverse climatic conditions.

Not every airplane radio is tested in a *high altitude* chamber. Such cabinets are used primarily for testing new equipment and spot checking production runs.

Radio and electronic inspectors, technicians, and engineers come in contact quite often with test procedure incorporating test chambers and, therefore, a brief explanation of the operation and use of these all-weather all-altitude rooms will be helpful to you.



Courtesy Tenney Engineering, Inc.

Figure 374. Test chamber capable of producing atmospheric conditions encountered in the stratosphere. Temperature down to —70° F. may be produced. The working space provided for equipment to be tested is 3 feet wide, 3 feet deep, and 4 feet high.

Construction and Method of Creating Required Conditions. As already mentioned, each test chamber is designed for a specific purpose which determines what functions are included and what extremes in temperature, humidity, and pressure (or vacuum) will be needed. Our discussion will cover a high altitude type of chamber used primarily for testing aircraft radio equipment.

The required pumps, heaters, blowers, and refrigeration equipment is included in a large cabinet which also provides the needed work space for the radio equipment to be tested. The units are rated in terms of the conditions they are able to create and the area of the space available for the equipment to be tested. For visibility a plate glass window is built into the door and other windows may be included in the walls. These observation ports are insulated by

See the description under the illustration above.

(*Continued on page* 364)

LESSON 52

Radio Servicing Technique

Since the radio field is the largest if not the most important branch of electronics, the greatest number of technicians find well paying work repairing radio receivers and transmitters, working in technical jobs at radio factories, or maintaining radio equipment for industrial firms.

OPPORTUNITIES IN RADIO SERVICING. As radio receiver circuits became more complex, the high school experimenter, amateur electrician, and the jack-of-all trades who attempted to repair everything, had to resign radio repair work to men who spent time in studying and were prepared for this important work. The additional information presented in this and the next lesson should enable you to repair successfully any radio set which developed a fault. The basic principles you have learned in the earlier lessons will now be applied. You will find yourself ready and able to repair radio receivers quickly and efficiently. Your customers will be pleased with your work and will be willing to pay a fair price. Because of your ability and speed, you will complete each job in the shortest possible time. This fact is important since you charge for the job and not for the time. Your customers do not care how long a job takes — they want the radio repaired. If another, less efficient serviceman takes three times as long as you to complete a certain job, his work is not worth a penny more and perhaps less.

On most jobs, it takes a great deal more time to find the fault than to complete the actual repair.

Jackson Electrical Inst. Co.

Figure 375. Every airplane carries extensive radio equipment for two way communication and for aid in safeguarding the flight. This equipment must be checked, adjusted, and repaired from time to time.

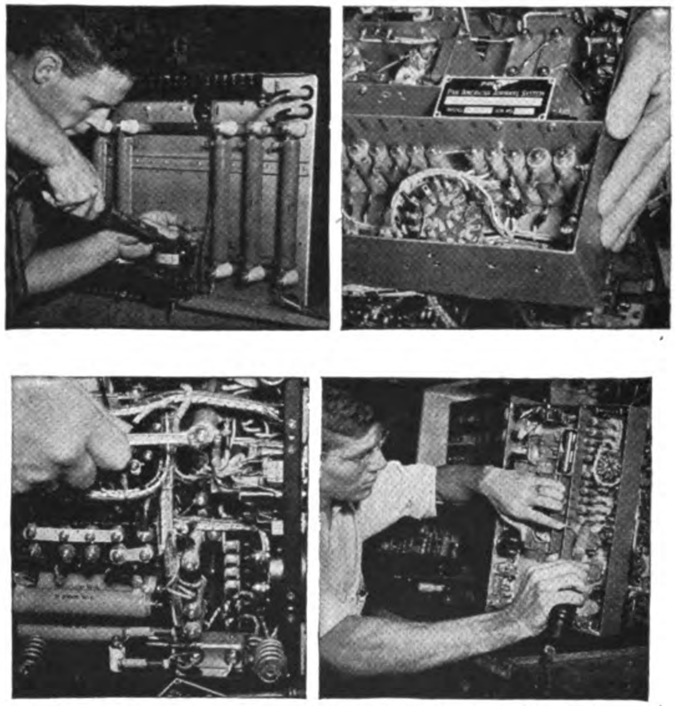
Each modern airplane carries so much radio equipment that a crew of radio servicemen is needed to check the various receivers, transmitters, direction finders, and inter-communicators from time to time.

The movable rack assembly illustrated is used electronically to check powder charges used in shells. This equipment was developed by engineers of the *Du-Mont Laboratories.* Radio servicemen may find interesting work building, operating, or repairing such electronic equipment.

In this section an assumption is made that you will operate your own radio repair shop or store.

There is an actual shortage of radio servicemen at present and the men in this profession are very well compensated. After the War, the opportunities for a *good* radio serviceman should continue.

WHAT IS EXPECTED FROM A RADIO SERVICEMAN? Usually, a radio serviceman operates from a small shop or his home and undertakes to repair, adjust, and improve radio receivers. He may be called upon to repair electronic equipment of the simpler type — the more complex devices are usually serviced by the manufacturer. The needed repair may be performed in the home of the customer, but greater freedom from possible annoyance and better facilities can be obtained in your own shop. Some servicemen are employed by factories to repair radios not meeting production tests or returned from the field while still within their 90 day guarantee period.



Courtesy Pan American World Airways

Figures 376 to 379. The work of testing and repairing radio receivers and transmitters is a highly technical occupation. The work is interesting and the salaries are good.

Honesty pays in all work and radio servicing is no exception. Make a fair charge for the work and parts needed, explain these charges to your customer, guarantee your work. Perform no actual work free of charge. Your prospects do not expect you to be a good radio serviceman if you inspect radios free, test tubes free, and offer other inducements.

METHODS FOR SECURING WORK. We live in a highly competitive society and, in normal times, a serviceman must *hustle* for his work. If you want more service business, if you want the business of people who never heard of you, you must let all know of your existence, your good points, and your special abilities to be of service. You must approach these prospects many times in many different ways. Various forms of advertising will do this job for you.

Among the various forms of advertising suitable for a radio service business, advertising in publications such as local newspapers and telephone books is most common. An advertisement may be sent directly to a prospect at his home address. A postal card, letter, or a special mailing piece may be employed for this *direct mail.* Posters, window displays, and signs are very effective ways for obtaining additional work.

Advertising in any form must get attention to be useful. Attention may be obtained by sheer size, black type, white space, color, novelty, illustration, or catch-phrases. Once the attention is arrested, the interest of the reader must be held. The story, the picture, the idea must compel the reader to continue. With the reader expressing a not personally realized interest in your advertisement, the next step is to create a *desire.* A desire for better tone, superior reception, improvements possible with a new set of tubes.

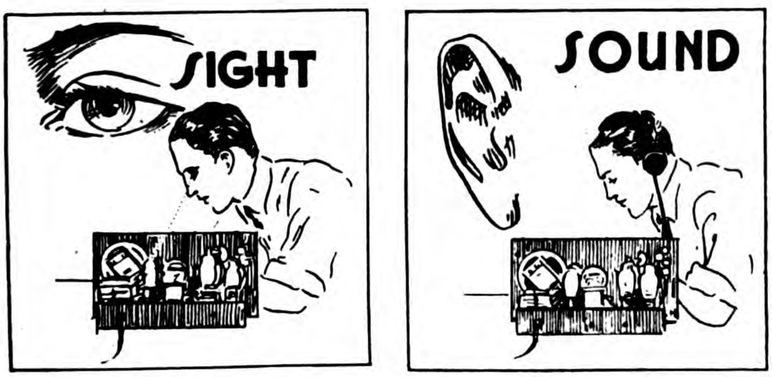
Once the desire is aroused, the reader must be impressed with the conviction that your tubes, your service, or your appliances are what he wants. Your items or service must appear to him as the logical solution of his needs. And the final step, you must make the reader act. Action will make your future customer pick up the 'phone and call you or perhaps stop at your store.

If there are other radio shops in your city, you may get valuable ideas by studying the methods used by others. Try to be original and improve on the work of others.

The usual advertisement placed by a radio serviceman is very simple. Words like: *Quality Radio Repairing* or *Let Us Repair Your Radio* are used, followed with a suggestion that rates are reasonable and the work is guaranteed. Make it easy for the prospects to find you or to call you. Give your complete address and telephone number.

INFORMATION SUPPLIED BY THE OWNER. In all cases, it is a good idea to ask the owner of the radio set requiring the repair to explain just how the faulty operation developed. In many instances, the information supplied will be of no particular use, but the occasional possible hint may save much time in locating the fault. The owner, for example, may say that smoke came out from a part and point to the power transformer. This would immediately suggest to you that some fault developed which caused excessive current drain from the transformer, or perhaps a short-circuit occurred in the transformer itself.

The owner of the radio to be repaired likes to be of assistance and is flattered by your questions.



Figures 380 and 381. Many radio faults can be detected by a simple visual examination of the radio chassis. Certain unusual sounds heard with the aid of the loudspeaker or with a pair of headphones connected to the audio stages can be used to suggest the possible trouble in the circuit.

VISUAL EXAMINATION. Surprising number of radio faults can be discovered by a simple visual examination of the radio chassis requiring repair. Suppose the complaint was poor tone. You notice that a push-pull output stage, 45's used, one of the 45's had no glow of the filament with the set turned on. Yes, the *no-glow* 45 tube was burned out, the circuit out of balance, the biasing resistor too small for the single operating tube, and possibly no by-passing of the resistor, thus reducing sensitivity.

The faults mentioned are only suggestive. There are hundreds of possible faults that can be discovered with a visual examination.

The fact that you own good service equipment does not mean that you must use it on every job. You can eliminate the wear and possible damage to your equipment, and save time besides, by following the suggestions given.

Faults such as burned out vacuum tubes, slipping dial cables, leaking electrolytic condensers, can be discovered by visual examination. In the case of a noticeably burned carbon resistor, suspect a shorted associated by-pass condenser. This resistor should also be replaced in such cases. It pays at all time to try to locate the difficulty by a quick examination before using test equipment.

Figures 382 and 383. A smoking part will indicate a probable fault in the associated circuit. Touching the grid caps and other *sensitive* points will produce results which may suggest the stage or part at fault.

The many diagrams of typical circuits presented in the latter part of this lesson will help you locate the various stages (and the order) in radio receivers you will be called on to service.

Since the voltage on the grid of any tube used in a radio receiver is very low, you are safe in touching this connection. To eliminate the possibility of receiving even a small shock, do not touch any metal or the chassis while making this test. The lead-in from an outside antenna (if one is used) may be used instead of the finger for this test.

Simple Tests for Locating the Fault. In your studies, you have already learned about many short cuts for finding the particular section of radio receivers or electronic equipment which is at fault. The usual practice with or without test equipment is to determine whether each stage in progressive order is in proper operating condition. In radio receivers, the test procedure resolves around the introduction of a suitable signal in each stage beginning with the last audio stage that is coupled to the speaker. It is possible to use a moist finger in contact with the grid as the means of creating the signal needed. Touching, for example, the grid of the audio voltage-amplifier tube would cause a loud hum to be produced, provided, of course, that this stage, the last audio stage, and speaker are in operating condition.

There are many short-cuts in servicing that will completely eliminate difficulties and are very easy to apply. Consider the instance of hum developing on strong local stations. This fault often may be completely solved by connecting a .1 mfd. 600 volt paper condenser from one side of the transformer primary to the chassis of the radio set. This keeps the radio set from being modulated by A.C. when tuning in a strong carrier and many sets are supplied with such condenser arrangement.

Such faulty electrolytic condensers should be removed from the radio and junked. Do not leave such capacitors in the circuit after you connect a replacement in their place.

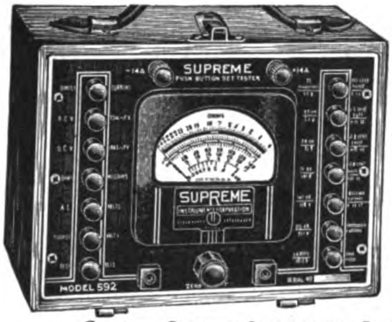
Electrolytic capacitors sometimes fail to filter properly the circuit and under careful test will show only a fraction of their original capacity. If the electrolytic condensers do not appear to be in good shape and the set has a loud hum, it is best to replace these units. If the complaint of hum really has no bearing, but is due to too critical a listener, an 8 mfd. or larger condenser placed across the filter circuit will solve this problem.

If you have already repaired a few radios, you will certainly agree with the author on this point.

Service Procedure. The task of repairing a radio set may be considered to consist of (1) the finding of the fault and (2) the actual repair. The task of locating the actual fault is usually the more difficult and requires a longer period of time than the actual mechanical repair. The finding of the fault resolves in the use of such equipment which will suggest the location of the improperly functioning part or circuit. The knowledge of properly operating

circuits of a similar type will serve as a guide. Once the fault is discovered, the repair becomes a simple matter of removing the short, completing the broken circuit, replacing the damaged part, or making the needed adjustment.

Let us discuss the method for locating the fault in a radio receiver. If the receiver is *dead* (no sound can be obtained from the loudspeaker), make certain that the power connection is made. Check availability of power at the socket by connecting a lamp or a test bulb. See that some antenna wire is connected to the radio. Your finger in contact with the antenna wire will complete the circuit which will permit your entire body to act as an antenna for test purposes. If no operation is obtained, remove the chassis from the cabinet. Suggestions for this work were given in Lesson 1.



Courtesy Supreme Instruments Corp.

Figure 384. While many radio faults may be detected without the aid of instruments, test equipment is of great help on some jobs. A volt-ohm-milliammeter, like the one illustrated, is very helpful for localizing the fault quickly.

The power supply should be examined next. The presence of filament voltages may be tested with an A.C. voltmeter. The presence of plate voltage can be checked at one or two points. For this purpose a high voltage (0-500 volts) D.C. voltmeter is used. If equipment is not available, the filament voltage can be checked by noticing the glow inside the glass type tubes. In A.C. type sets, the filament connections to any one tube may be shorted with a piece of wire and the presence of a spark will indicate the presence of voltage. The fact that plate voltage is available may be observed with the aid of a paper or electrolytic condenser. Connect the condenser momentarily to a point where positive plate potential should be present and to the chassis. The condenser should take a charge. Now disconnect and bring together the two leads from this test-condenser. A spark will be noticed at the point of contact if a voltage (of 50 volts or more) was present between the points of the circuit mentioned.

If you fail to obtain the voltages expected, the fault lies in the power supply. However, if the apparently correct voltages are obtained, the different stages of the receiver must be tested in order. The technique which is explained next is also applied in case the radio is operating very poorly.

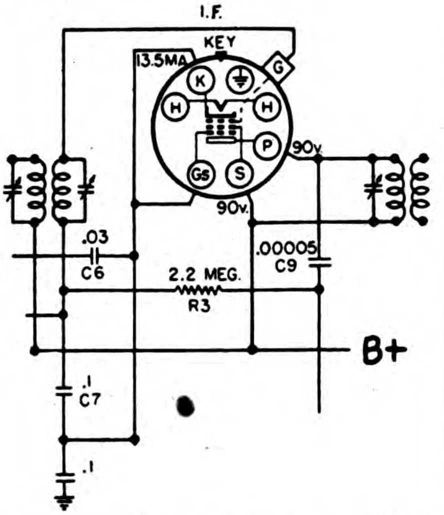
By injecting a signal from a suitable signal generator in one stage at a time, the portion of the receiver failing to give proper operation can be discovered. We have already mentioned this method earlier. In case a signal generator is not available, a moist finger or a long piece of wire in contact with the control grid of the tube in the stage under test, will serve as the source of signal. The use of a signal generator, of course, will give much more

You may learn that the owner of the radio already made all these simple tests.

During 1942 and 1943, no test equipment for civilian radio servicemen has been manufactured. It is not likely that any such equipment will be made during the War. You may be able to buy some second-hand equipment from your local radio jobber, or from a former serviceman who may be going into the Army or other type of work. Do not try to buy too much equipment now; the test units after the War will be of improved type and will be lower priced, in all probability.

A capacitor from 1 to 4 mfd., 450 WV., is recommended for such tests. With an electrolytic condenser, polarity must be observed.

If you are asked to repair a radio which has the fault appear from time to time, but the shaking of the cabinet, movement of the volume control, or turning on an electric light will make the radio operate normally for a time, you have real trouble on your hands. Such condition is called intermittent operation and is difficult to repair. Experts usually replace condensers and resistors one at a time until the one causing the trouble is found.



The circuit of an I.F. stage of an AC-DC superhet.

accurate results and will permit you to judge with greater assurance whether a stage is *good* or *bad.*

How to Find the Actual Fault. The localizing test you have used will point to the section of the radio receiver at fault. In one case, let us say, the trouble seems to lie in the section between the I.F. tube and the detector. This means that your early tests produced the expected response when the signal was injected into the detector, but not at the I.F. tube.

If the tubes have not been tested initially, first test the tube used in the I.F. stage. This I.F. tube is a part of the section at fault. Next, the circuit of this suspected section should be examined and a diagram is helpful for this purpose.

Our condenser test-unit or a voltmeter may be used to determine if the expected voltages are at the plate of the I.F. tube, screen grid, and the B+ connection of the I.F. transformer (usually the red lead). If the condenser test-unit is used, connect one lead to the chassis, and touch the other to the points mentioned. A voltmeter is used the same way, but will indicate exact voltage. In an AC-DC type of radio, about 100 volts may be expected at the points mentioned; in A.C. sets with transformers, 200 to 250 volts. An I.F. stage from an AC-DC set is illustrated.

Lack of voltage at a point where it is required and expected indicates that either *it* cannot get to this point because of a part being *open* or wire broken, or because an associated by-pass condenser is shorted and passes the voltage to the chassis. This means we will look for broken wires in wiring or coil, or shorted circuit, or try disconnecting condensers one at a time.

The process of finding a radio fault is electrical, but the actual repair work is usually mechanical in nature.

When you finally locate the actual source of trouble—a shorted condenser, two wires touching, or an open winding in a coil—you are ready to do the mechanical work to complete the repair. It is important, of course, to select proper replacement for the faulty part and to do a good mechanical job of mounting the new component.

Similar abundance of information is present in the circuit of the radio you may be working on.

Using Circuit Diagrams as an Aid. Probably you cannot see how a single diagram can give 1,000 facts about the circuit, but it does. Let us consider the diagram of a seven tube *Pilot* set.

Here is the general information about the complete radio set:

You should be able to see why this information is apparent from the schematic of Figure 385.

This is a seven tube radio using a tuning eye tube and designed for A.C. operation. The set covers two bands and has a novel arrangement of pilot lights for band indication. Assuming single dial control, band switch, tone control, and volume control, there should be four knobs employed. A dynamic speaker is used and is indicated as a 6-inch unit. The set is a superhet using one stage of I.F. Of interest is the resistance-capacity coupled R.F. coil giving superior tone quality. Also note that the I.F. transformers, marked 73288-E, are of the permeability tuned type. These general facts are only a few of the many which can be found by examining this diagram.

Here is the basic information about the audio output stage:

The power output stage employs a 6F6-G pentode and is resistance coupled to the previous triode. This tube is coupled to the voice coil of a dynamic speaker by means of an output transformer. From a tube chart it is easy to learn that the power output is about three watts. A tone control is incorporated in this circuit.

Charts are in Lesson 9, Volume 1.

Here is the specific data about the same stage:

If we analyze this same stage with greater detail, we can obtain specific information on the value of each condenser and resistor used. Many of these parts are also listed with exact manufacturer's numbers. Circuit details also can be found. For example, a .05 mfd. condenser is used as a tone compensator and the tone control consists of a series condenser and variable resistor and is also placed in the plate circuit. Of interest is the biasing method used for this 6F6-G tube. The cathode is kept at a ground potential and the .02 mfd. condenser serves as a grid return decoupling by-pass. The total drop in the negative leg of the power supply (in the 250 and 50 ohm series resistors) is used for this purpose. The voltage at the tap of these two resistors is used as the minimum bias for the tubes with A.V.C. This will give you an idea what we mean by specific data and, of course, there are plenty more facts.

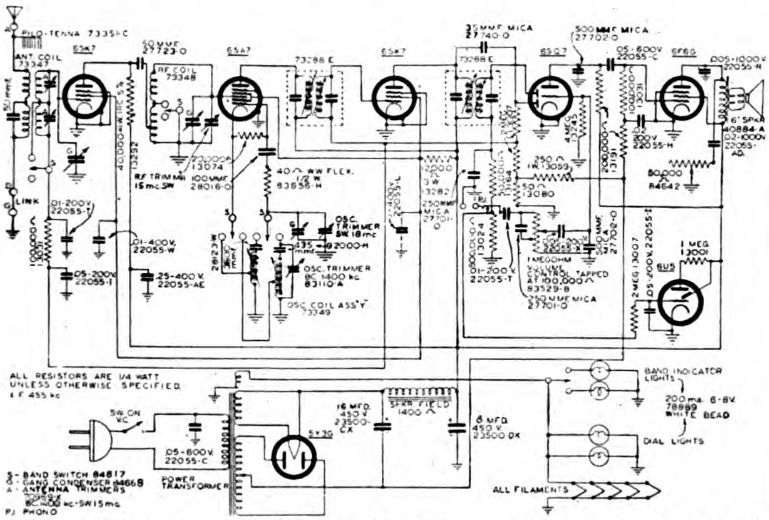


Figure 385. A circuit diagram of a radio receiver presents a wealth of information about the components used, suggestive test procedure, and serves as an aid which enables the serviceman to locate the fault in the minimum of time.

And here is the specific information about one part—the plate coupling resistor of 6SQ7 tube, part 13191:

This resistor has a resistance value of 200,000 ohms, as marked. It is used to load the triode section of the tube mentioned and carries the plate current for this tube. Without consulting tube characteristic information, you can guess that the current is in the order of a few milliamperes. Applying the wattage formula: Watts equals current in amperes multiplied by itself, multiplied by the resistance, we can find the power handling requirements of this resistor. (Actual problem: about .002 x .002 x 200,000 equals 0.8 watts; probably one watt resistor used.) An important fact to notice is the possibility of this resistor to burn out if the plate R.F. by-pass 500 mmfd. condenser shorts.

Now consider the several stages used as well as the power supply, multiply this by the many different parts used in each stage, multiply this by facts known to you in general but made specific with the aid of a circuit diagram, and you have the helpful information needed to service the set quickly and efficiently.

CIRCUIT DIAGRAM DATA

A component of correct electrical values and of any make may be used for replacement purposes.

Information on the tube connections is found in characteristic charts or a tube manual.

Please understand that similar information is presented by the circuit diagram about all other parts used in the receiver.

SIMILARITY OF CIRCUITS

It is important for you to realize these limitations and know how to apply your knowledge of circuits to figure out missing facts.

WHAT A DIAGRAM DOES NOT TELL YOU. But a diagram does *not* tell you many things. Sometimes the non-indicated data can be found in the actual radio, or figured out by reasoning or formulas, or obtained from a parts list. Let us see how this additional information may be obtained.

In the previous section, we assumed that there were four control knobs from the data given in the circuit. This, of course, can be checked by examining the chassis itself. Using a formula for wattage, we have also calculated the wattage of a resistor.

This still refers to Figure 385.

Now looking back at the circuit we have been using in our discussion, we notice several switches marked "S" located in different sections of the circuit. The foot-note in the lower left hand corner of the diagram, tells us that this is the band switch and these many separate switches must be controlled by a single knob. This fact, you will notice, is not obvious from the circuit, but can be understood by an experienced radio man with the aid of a diagram.

Information on number of turns in a coil, the type of base used for pilot lights, and other such facts are not often included.

TYPICAL CIRCUITS ARE SIMILAR. According to the best estimates, there are in the U. S. close to fifty million radio sets made up of about 20,000 different models. There are many ways to classify these different sets, but if all similar types are grouped together, you will find only a handful of types. And even these types, few in number as they are, can be seen to have many similar sections and can be tested and serviced along the same lines.

If you have done extensive radio servicing, you probably have realized this fact.

Circuits have changed more with time than through any other influence. The group of early electric radios from about 1926 to 1929, were of the TRF type and used 26's or 27's for the RF and AF stages. These are similar triodes. A type 27 tube was used as a detector. The final audio output stage used a single or push-pull triodes of 71A or 45 type. The speaker was usually dynamic.

Type 24A tubes for R.F., and 47 output pentodes came a little later.

Many sets sold during the 1930 depression were of the four tube midget variety. These were for A.C. and for AC-DC operation. As some of the later larger TRF sets, these midgets employed type 47 or other pentodes in the output. In the A.C. midgets an 80 tube was the rectifier. At first, type 24A or similar type 35 tubes were used in the R.F. stage and detector. As new tubes were developed in 1931-32, type 58 was used as R.F. and 57 as detector. Then, of course, came other similar tubes in the 6.3 volt series, and in metal types.

You must realize that the variety of tubes listed in Lesson 9, were developed over a period of time.

The early AC-DC sets used 6.3 and 25 volt tubes, dropping the balance of the line voltage with a line cord resistor or ballast tube. You will find that even present day *small* TRF circuits are exactly the same as these early types.

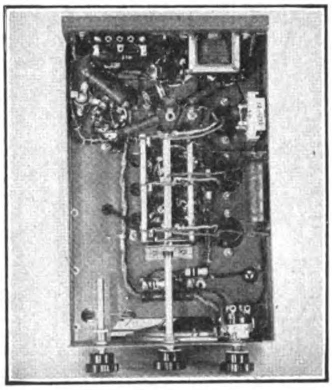
You must not be confused with minor variations in circuits or different placement of parts. Good training, at this point, is to examine many diagrams of radio sets and notice the similarities. Also, remember that the physical appearance of parts does not have an effect on the electrical similarity of radio sets. Five inch and twelve inch dynamic speakers, while giving results which are really different, electrically behave very much alike.

While a few models of TRF sets using later tubes were manufactured, after 1932, practically every radio of five or more tubes was of the superhet type. You already know that one of the characteristic things about all superhets is the use of I.F. stages. These stages are basically alike, with only a few minor variations and sometimes different I.F. frequencies. There is complete similarity even in the I.F. stages of battery sets, auto sets, and others.

The plate power and filament supplies of all AC-DC type sets are similar. The audio sections of all radios are very similar.

The oscillator-mixer stages of the early superhets were different from today's type. Sometimes, two tubes were used for this application — one was the oscillator, the other the mixer. In special circuits, R.F. pentodes were sometimes used alone. The pentagrid converter tubes operate very much like two individual tubes combined in a single glass envelope. In all superhet oscillators the plate current must be controlled by two different frequencies — the incoming station frequency and the oscillator frequency. This latter frequency can be generated by the same tube or by another triode. The function is seen to be the same, but the method differs.

To summarize, radio circuits are made up of similar sections usually placed together in the same manner. Ordinarily, there are only physical variations in parts used and their placement, and minor differences in the circuits. Since new radio developments are available to practically all radio firms at the same time, and since each tries to make their sets best within a price limit, the resulting radios must be somewhat along the same lines.



Courtesy Kaar Engineering Co.

Figure 386 and 387. Receivers used for special applications are similar in design and appearance to broadcast home-type radios and are serviced in the same manner.

EARLY A.C. TRF RECEIVERS. Very few of the old battery operated receivers are still in use. But because the early *all electric* sets were produced in tremendous quantities and because these sets are capable in giving acceptable reception from local stations, these sets are found in many homes at the present. When millions of certain models* are in use and these radios are on the average over fourteen years old, many of these receivers will require repairs.

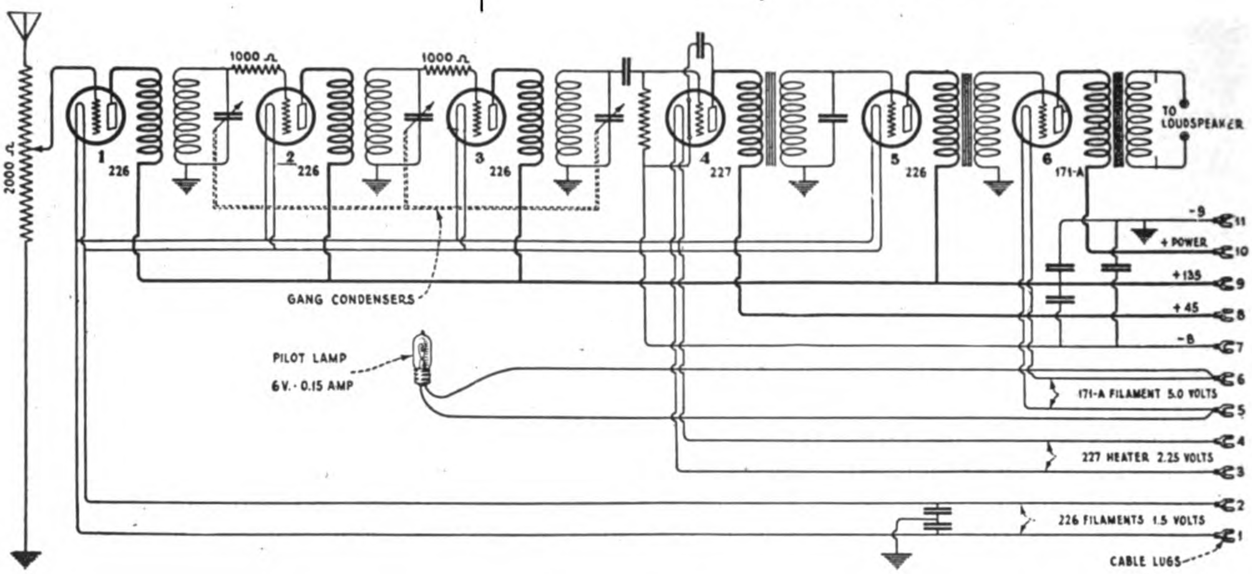
The receivers produced during 1926 and 1927, used type 26 tubes in majority of the stages. These sets were of the tuned radio frequency type and used three or four R.F. stages. A grid leak detector was usually employed and a type 27 triode was used in this function. The output stage may have used a single or push-pull type 12A, 71A, or 45 triode. The R.F. stages used a multi-gang tuning condenser and an attempt was made to shield the different stages. The audio stages were coupled with transformers. The power supply, in these early radios, were at times mounted separately.

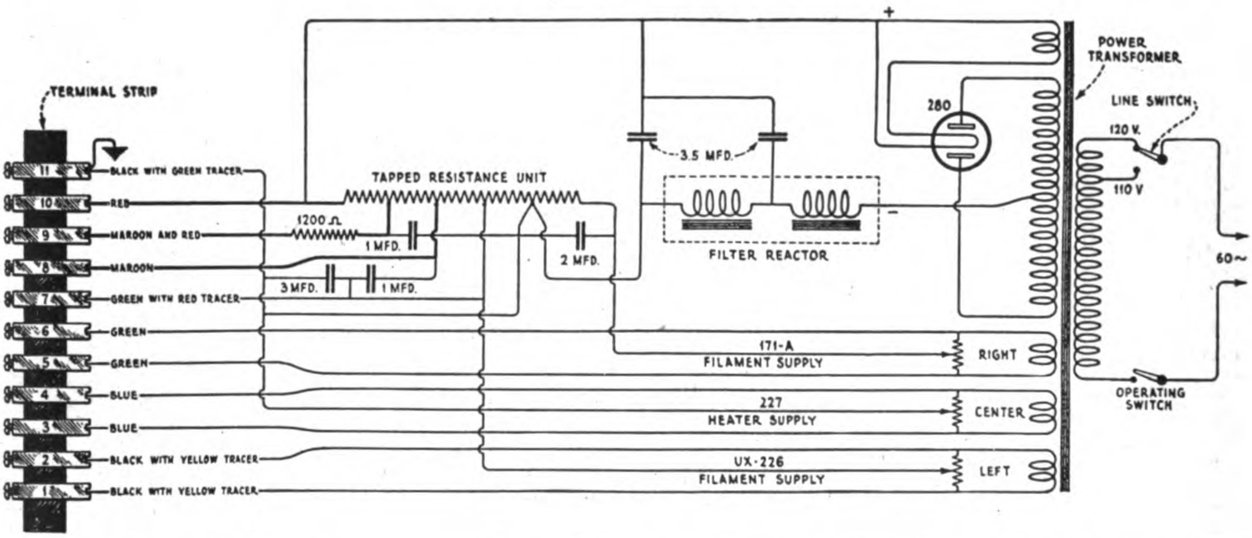
The receivers of a little later period used type 27 triodes throughout, except in the power output stage where type 45 tubes in push-

This paragraph tries to explain that various oscillator-mixer stages are similar in function, and are tested and serviced in a like manner.

In many instances, new patented developments are released on a license and royalty basis.

***We list below several of the more popular models of this type:**
Atwater Kent 40.
Crosley Model 706.
Gloritone 26.
Kolster K-20, 22, 27.
Majestic 70 and 90.
Philco 82 and 86.
Philco Model 87.
RCA Radiola 17, 18, 60.
RCA Victor R-32, R-52.
Sparton 930 and 931.





Tubes used in similar models:

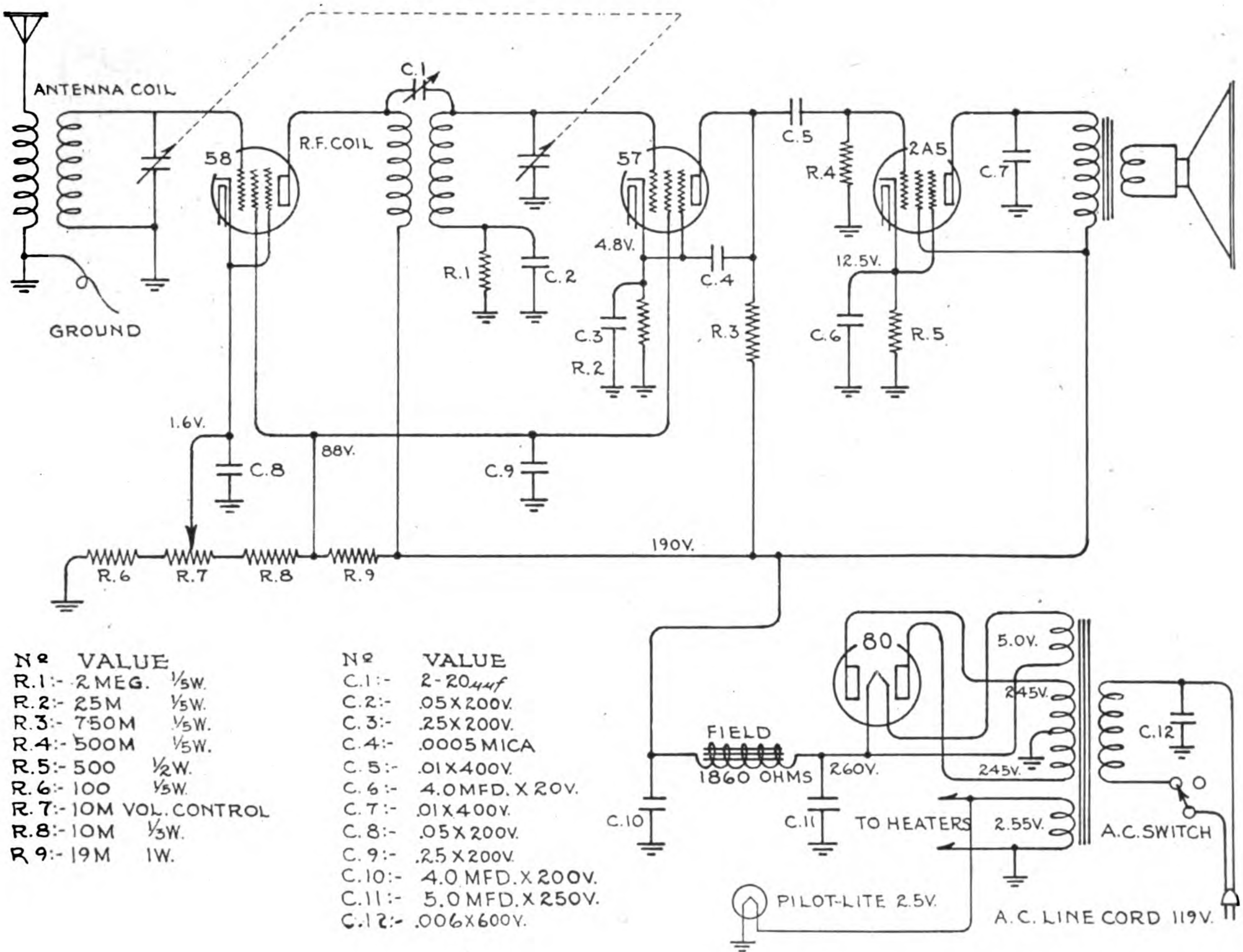
R.F.	**26, 27**
Detector	**27**
Audio Amplifier	**26, 27**
Power Output	**12A, 45, 50, 71A**
Rectifier	**80, 81**

pull were employed. The tetrode tube was commercially produced at about this time (1929), and type 24A tubes were used in the R.F. stages. Type 27 tubes were still used in the detector and audio voltage amplifier stages. The type 47 power pentode was developed soon after this and was introduced in the output stage.

Above we have a circuit of a TRF receiver which is representative of this period. This diagram can be used as a guide for the analysis of all circuits of similar type. Let us become acquainted with this circuit.

The receiver and the associated power supply were on separate chassis, usually inclosed in very sturdy and solid metal containers. A cable was used for connecting the two units together. In its basic function, the power supply circuit is of the familiar type. The more economical higher-capacity electrolytic capacitor did not *come* until a few years later, and bulky *paper* condensers of relatively low capacity are used in the circuit shown. In making the

(*Continued on page* 357)



Nº	VALUE
R.1:-	2 MEG. 1/5W.
R.2:-	25M 1/5W.
R.3:-	750M 1/5W.
R.4:-	500M 1/5W.
R.5:-	500 1/2W.
R.6:-	100 1/5W.
R.7:-	10M VOL. CONTROL
R.8:-	10M 1/3W.
R.9:-	19M 1W.

Nº	VALUE
C.1:-	2-20 μμf
C.2:-	.05 X 200V.
C.3:-	.25 X 200V.
C.4:-	.0005 MICA
C.5:-	.01 X 400V.
C.6:-	4.0 MFD. X 20V.
C.7:-	.01 X 400V.
C.8:-	.05 X 200V.
C.9:-	.25 X 200V.
C.10:-	4.0 MFD. X 200V.
C.11:-	5.0 MFD. X 250V.
C.12:-	.006 X 600V.

Analysis of the Circuit. The midget radios of the 1931-33 period were of the A.C. operated type. The circuits used a stage of R.F., a detector, pentode output stage, and a full-wave rectifier power supply. Various tubes were used in the different stages. The coils were of the unshielded type and usually the antenna coil was placed above the chassis, while the R.F. coil was placed at right angles and underneath the chassis. A two-gang condenser was used for tuning.

Please refer to the power supply section and notice that the speaker field is used as a choke. The voltage divider network is incorporated to give lower (88 volts) grid voltage and also serve as a bleeder through the volume control, R-7, as shown in the circuit. R-6 is used to assure minimum bias for the type 58 tube.

A power detector circuit uses a type 57 tube and adds to the gain of the radio. It is possible to quickly test a radio of this type by connecting the antenna to the plate of the R.F. stage, type 58 tube in this case. This action eliminates the preceding R.F. stage.

Pentodes of the power type were used in the audio output stage. This circuit employs a type 2A5, but type 47 was very popular at the same time, with types 41, 42, and 6F6 coming later. The con-

(*Continued on page* 356)

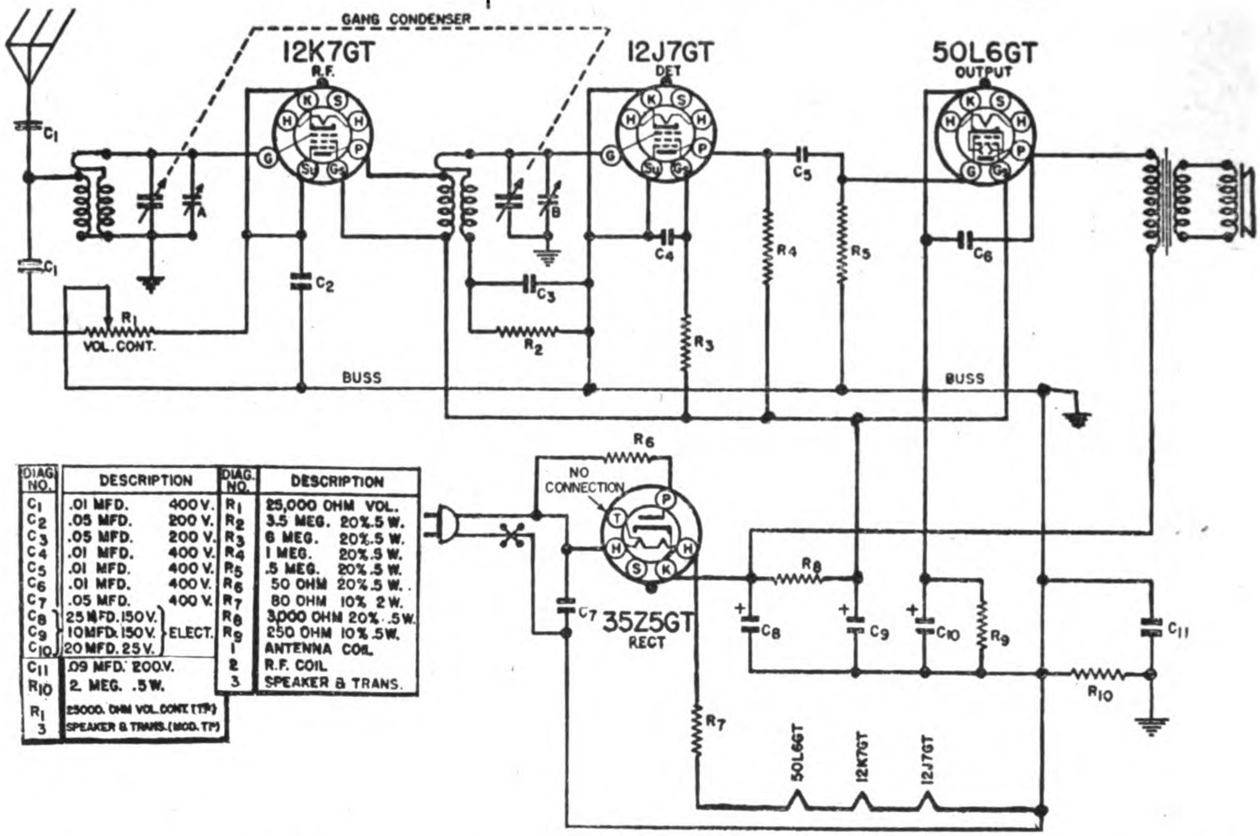
Tubes used in similar models:

R.F. **6D6, 24A, 35, 39/44, 58, 78**

Det. **6C6, 24A, 36, 57, 77**

Audio .... **PZ, 2A5, 38, 41, 42, 45, 47**

Rectifier .... **80, 82, (1V, 6Z4, 84)**



DIAG. NO.	DESCRIPTION	DIAG. NO.	DESCRIPTION
C_1	.01 MFD. 400 V.	R_1	25,000 OHM VOL.
C_2	.05 MFD. 200 V.	R_2	3.5 MEG. 20% .5 W.
C_3	.05 MFD. 200 V.	R_3	6 MEG. 20% .5 W.
C_4	.01 MFD. 400 V.	R_4	1 MEG. 20% .5 W.
C_5	.01 MFD. 400 V.	R_5	.5 MEG. 20% .5 W.
C_6	.01 MFD. 400 V.	R_6	50 OHM 20% .5 W.
C_7	.05 MFD. 400 V.	R_7	80 OHM 10% 2 W.
C_8	25 MFD. 150 V. ELECT.	R_8	3,000 OHM 20% .5 W.
C_9	10 MFD. 150 V. ELECT.	R_9	250 OHM 10% .5 W.
C_{10}	20 MFD. 25 V. ELECT.	1	ANTENNA COIL
C_{11}	.09 MFD. 200 V.	2	R.F. COIL
R_{10}	2. MEG. .5 W.	3	SPEAKER & TRANS.
R_1	25000. OHM VOL. CONT. (TP)		
3	SPEAKER & TRANS. (MOD. TP)		

Tubes used in similar models:

R.F...6D6, 6K7, 6SK7, 12K7, 12SK7, 78

Det. 6C6, 6J7, 6SJ7, 12J7, 12SJ7, 77

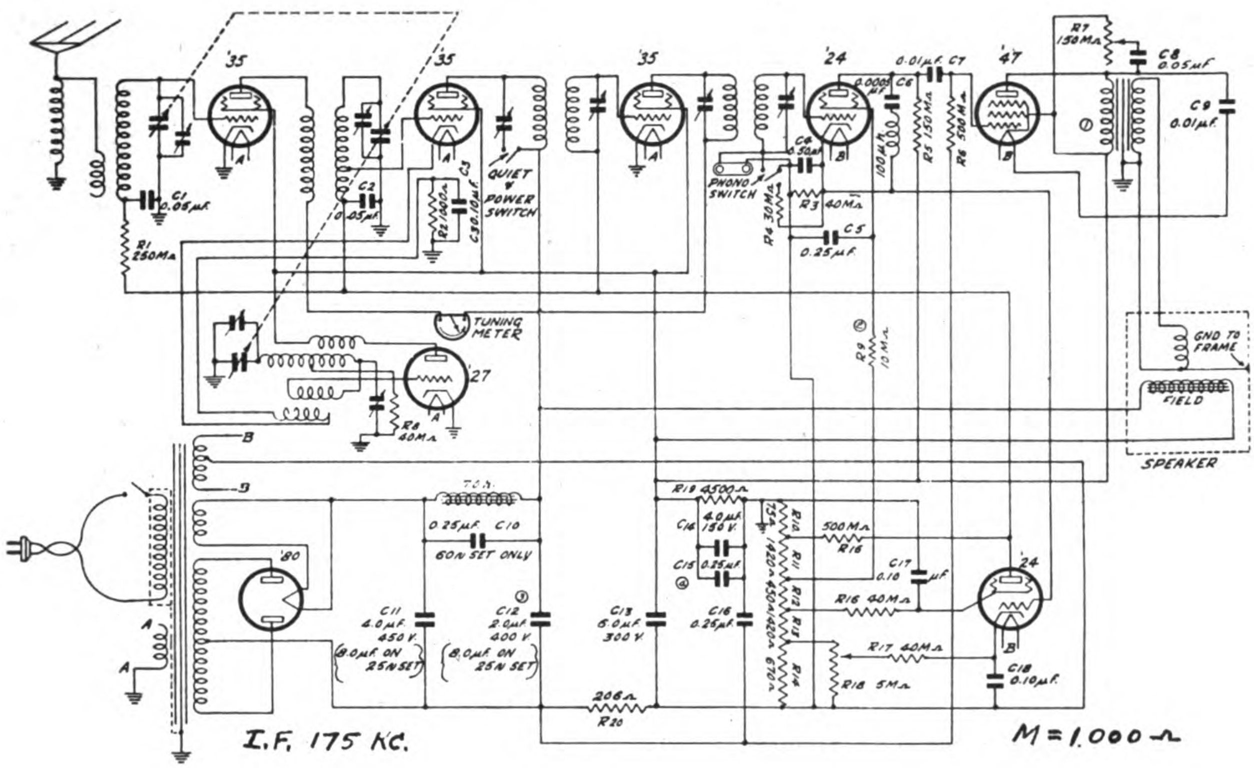
Audio .25A6, 25B6, 25L6, 35L6, 43, 50L6

Rectifier IV, 12Z3, 25Z5, 25Z6, 35Z4, 35Z5 (12A7, 25A7, 70L7)

Similarity to Other Circuits. This modern midget radio is a good example of circuit similarity. You will notice that the AC-DC power supply is basically the same as other supplies of this nature, studied in previous lessons. The R.F. and detector stages are almost identical to those of the circuit we have just examined, but since only 100 volts is applied to the plates of the tubes used in these stages, the same voltage, without any additional drop, also serves the screen grids of the two tubes. As you will see from the circuit, these voltages are not always applied directly to the tube elements, but may be applied through resistors or inductors.

In AC-DC radio receivers, many convenient short cuts may be applied to locate the fault. If a tube is suspected as being *burned-out,* you may use a 50 or 100 ohm resistor and connect it across the filament terminals of each tube in turn. If the balance of the tubes light up, with this test made at one socket, the tube in this socket is probably at fault. The same 50 ohm resistor may be used to test for B+ voltage at the proper points. The presence of voltage will cause a spark to jump when contact is just completed.

Point to Notice. The resistor R_6 is used to prevent sudden surges or a momentary short in the power supply, in damaging the rectifier tube. This resistor may be incorporated in any AC-DC power supply as a precaution. Rectifier tubes intended for AC-DC power supplies are easily damaged by momentary shorts which cause heavy current to flow. Such damage to the tube reduces the emission to a very low value although the tube continues to *light.*



Study of the Circuit. As mentioned in the text of an earlier lesson, the first superhet receivers used a separate tube for the oscillator. If you are servicing one of these older radios, you can easily detect the presence of this separate oscillator. Please notice that in this circuit the oscillator frequency is injected into the cathode of the second type 35 tube which is used as the mixer. A special cathode coil is employed for this purpose.

The first type 35 tube is used as an R.F. pre-amplifier.

One stage of I.F. is used, with a type 24 tube as the detector. The components in this detector circuit are critical and care should be exercised in making replacements.

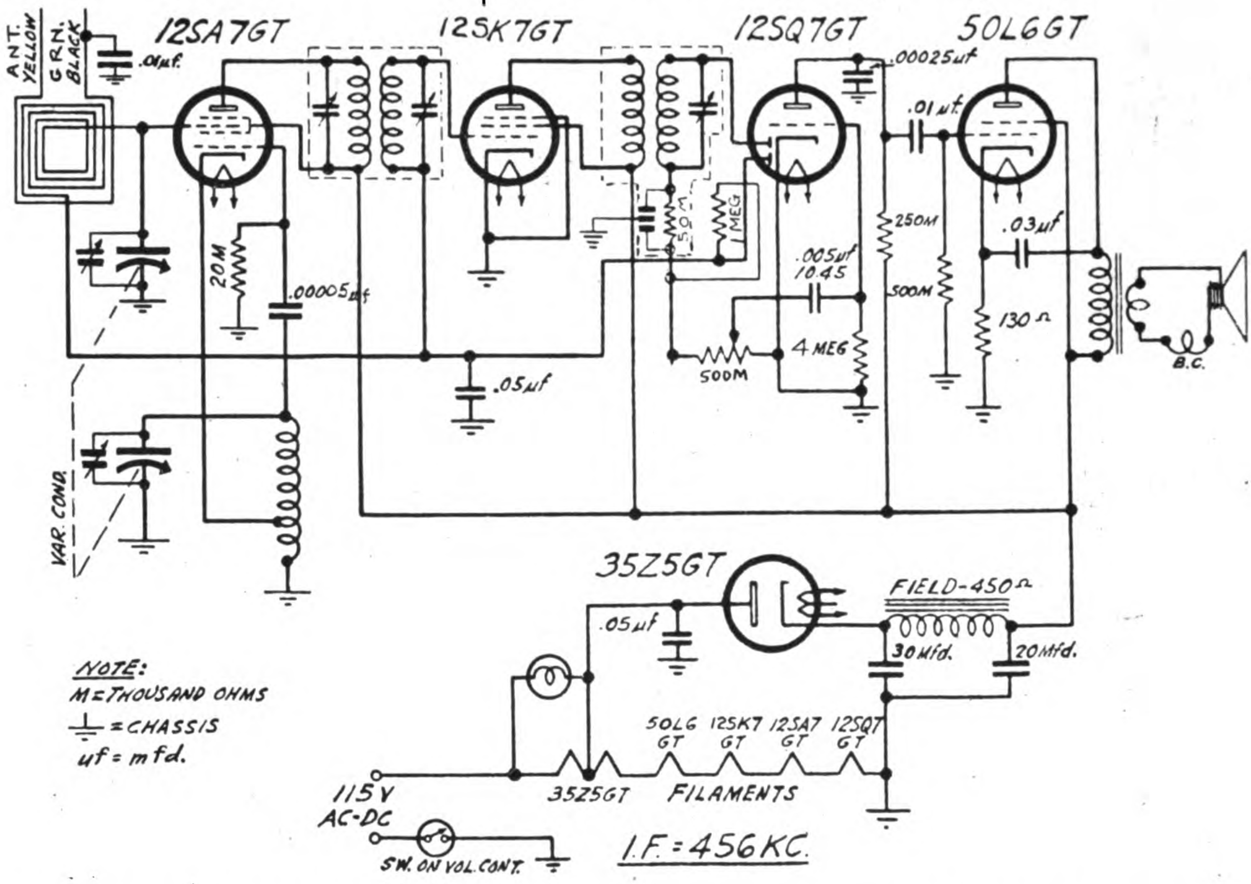
That is, second detector.

The type 24 (correct number is 24A) tube shown in the lower right-hand corner of the diagram is used in a AVC circuit of an earlier type. The bias applied to the R.F., mixer, and I.F. tubes is determined by the strength of the signal and the adjustment made on the R-18 potentiometer.

The condenser, C-10, is employed to *tune* the filter choke. This circuit makes the filter more effective in reducing the ripple and possible audio hum. In modern sets, the use of larger capacity filter condensers eliminates the need for such special circuits.

Notice the use of two condensers in parallel across a 4,500 ohm resistor marked R-19. When R.F. currents are carried by a long lead, by-pass condensers may be placed at two separate points. However, two condensers are used in this case because the larger one of 4 mfd. presents considerable inductive reactance to R.F. and actually acts as a choke. The smaller condenser, C-15, is used in parallel to by-pass R.F. from the screen grids of the tubes.

This is a good point to remember when servicing receivers which have a tendency to oscillate. The presence of a large capacity condenser cannot be taken as a guarantee of R.F. by-pass.



Tubes used in similar models:
Converter 6A7, 6A8, 6AS7, 12SA7
I.F. ...6D6, 6K7, 6SK7, 12K7, 12SK7, 78
Audio-Det. ...6Q7, 6R7, 6SQ7, 12SQ7, 75
Audio 25A6, 25L6, 35L6, 43, 50L6

Most Popular Midget Receiver. Superhets of the type covered by the above circuit have been sold in great number. Different tube types have been used, but the circuits have been essentially the same. Some of these receivers are of a similar type, but are A.C. operated.

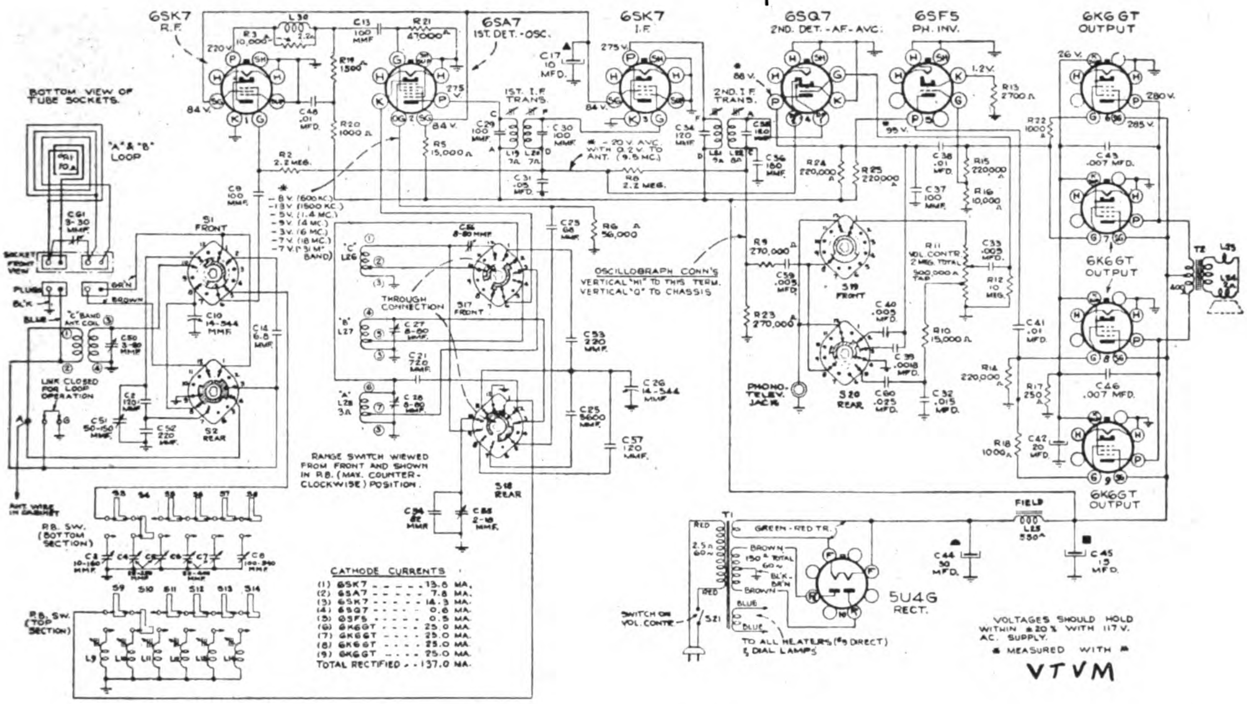
The power supply may be tested in the usual manner, and the *unbalance* test can be applied to determine in what stage the fault lies. The usual fault is due to a shorted condenser, bad tube, or improper alignment.

In case a signal generator is used for alignment, the I.F. stage is adjusted to the frequency specified, while the signal is injected in the last I.F. transformer and then in the preceding transformer. The alignment is next carried out by injecting the signal either by a connection to the antenna wire or by making a small loop of the signal generator bare lead. The adjustment at about 1,400 KC. is made with the trimmers of the condenser.

(*Continued from page* 353)

denser C-7 (about .01 mfd. in most sets) is used to by-pass some of the *highs* which predominate in pentode output tubes. In many sets, this condenser is connected between the plate and screen grid which, of course, is at a ground potential as far as audio frequencies are concerned.

RCA-VICTOR 110-K



Small Faults in Large Sets. You should realize that even a large complex receiver may stop operating because of a very minor and easily found fault. Bearing in mind that the large multi-band receiver consists of a greater number of individual stages of the type we have already studied, you will realize that the servicing procedure is similar. Examining the circuit above, you realize that four 6K6-GT tubes are used in the output stage and this stage may be tested in the same manner as any other audio stage. The phase inverter tube shown in the circuit corresponds to the second triode of the circuit we have studied in Lesson 11. The first tube of the phase inverter is the triode section of the 6Q7. The I.F. stage has nothing exceptional involved. The R.F. stage and oscillator are of the familiar type, but are made somewhat complicated by the band switch and push button arrangement. You will remember that once the receiver is made to operate on the broadcast band, any fault which may be still present on the short wave bands is due to the special short wave coils, switch contacts, or failure of the oscillator tube to operate on high frequencies.

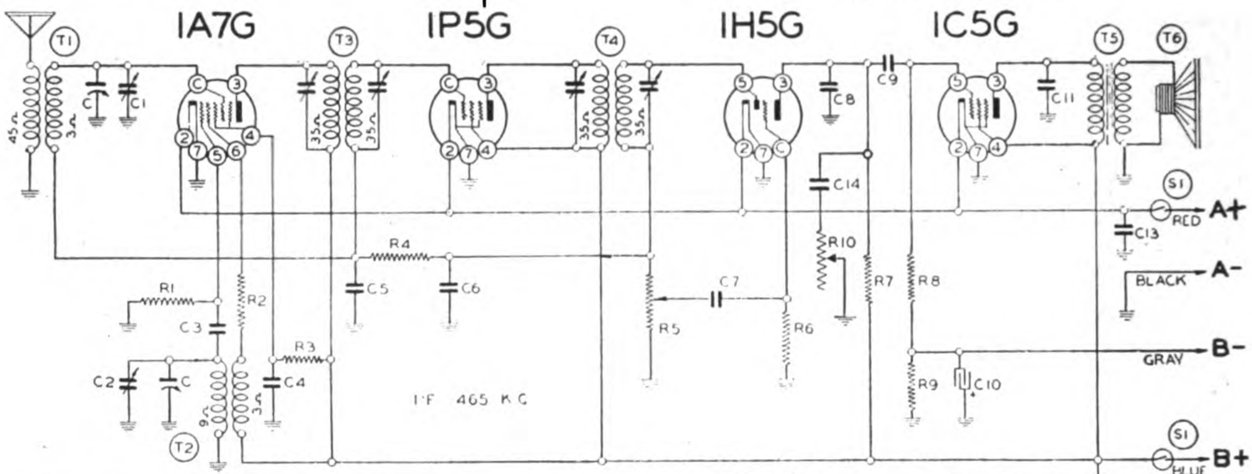
This circuit, for example, covers a receiver made up of the following stages:

R.F. pre-amplifier, 6SK7.
Pentagrid converter, 6SA7.
One I.F. stage, 6SK7.
Detector, A.F., AVC, 6SQ7.
Phase inverter, 6SF5.
Push-pull parallel audio output using four 6K6-GT tubes.
Full-wave rectifier, 5U4-G.

(*Continued from page* 352)

needed repairs, if you discover that one of these paper dielectric condensers is at fault, it may be replaced with a more compact electrolytic unit of greater capacity and of sufficiently high voltage rating. A voltage divider and its related by-pass condensers were also included in the power supply chassis.

The receiver circuit employs three stages of R.F. amplification. The antenna input stage is untuned and the 2,000 ohm potentiometer serves as the volume control and grid resistor. The 1,000 ohm grid resistors prevent oscillations, since triodes are used and there is considerable grid to plate capacity within the tubes.



RESISTORS

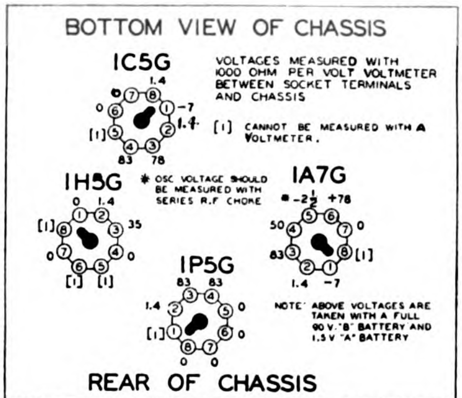
R1	200M ohm—⅓ w.
R2	4M ohm—⅓ w.
R3	40M ohm—⅓ w.
R4	3 megohm—⅓ w.
R5	1 megohm volume control
R6	5 megohm—⅓ w.
R7	500M ohm—⅓ w.
R8	1 megohm—⅓ w.
R9	700 ohm—⅓ w.
R10	Tone Control (1 Megohm)

CONDENSERS

C	2 gang variable condenser
C1	Antenna Trimmer on gang
C2	Oscillator trimmer on gang
C3	.00025 mica
C4	.05 x 200 v.
C5	.05 x 200 v.
C6	.0001 mica
C7	.003 x 600 v.
C8	.0001 mica
C9	.01 x 400 v.
C10	10 mfd. x 25 w. v.
C11	.003 x 600 v.
C12	.25 x 200 v.
C13	.1 x 200 v.
C14	.002 x 600 v.

PARTS

T1	Antenna Coil
T2	Oscillator Coil
T3	Input I. F. - 465 kc.
T4	Output I. F. - 465 kc.
T5	Output Transformer
T6	6 in. P. M. Speaker
S1	Off-on switch on Volume control



These 6-volt farm sets were similar to auto radios, but employed tubes of lower filament current requirements.

Probably all combination portables of the future will be of this type.

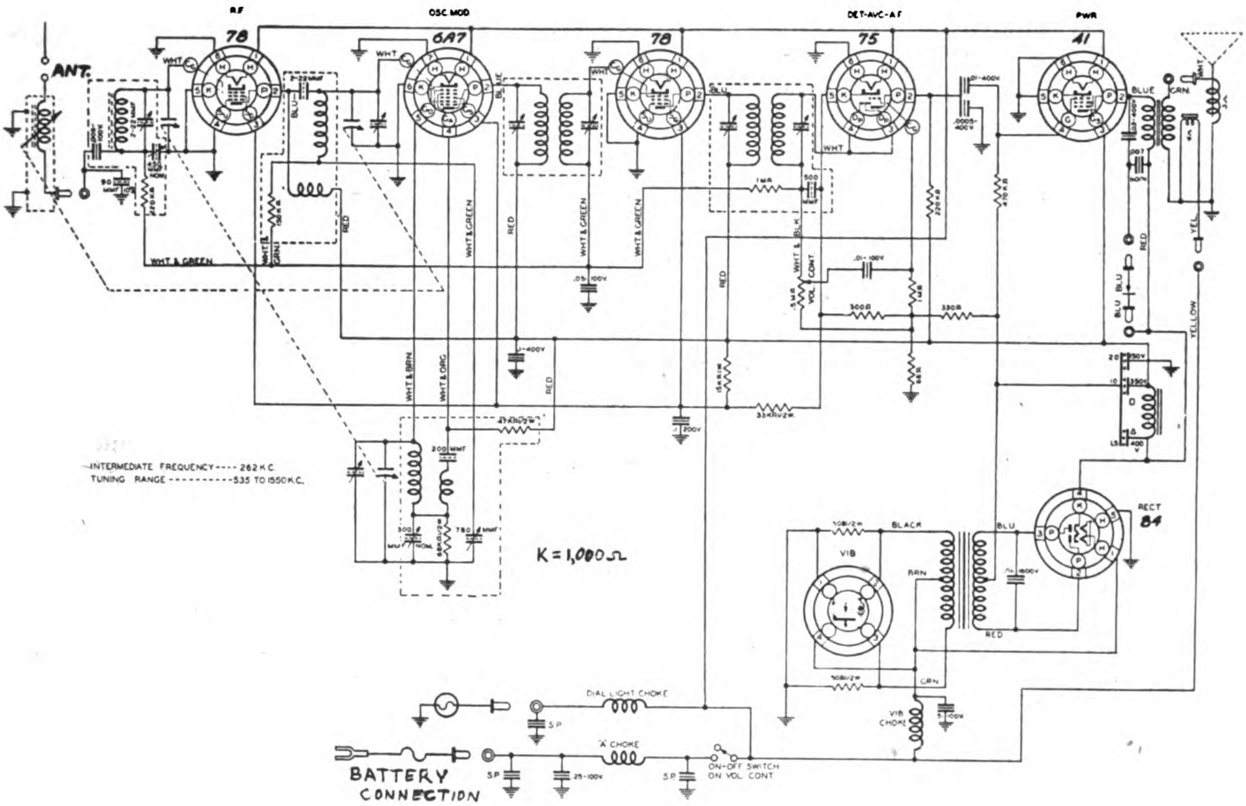
Use of Battery Tubes. The new series of battery tubes made possible the present-day portable receivers and *farm* type radios. The majority of these tubes have their numbers begin with "1" or "3," for example, 1H5, 3Q5. The older battery tubes were in the *30* series.

Essentially, the battery sets are similar to the types we have already studied, but the power is supplied from batteries, and the A battery, for filament use, may also be employed to give the needed bias in some of the stages.

Some of the older type farm radios at times were designed for six volt storage battery operation and the plate voltage was obtained with the aid of a vibrator type power supply.

Some of the modern portables incorporate an AC-DC power supply and permit the operation of the radio from the power line. Usually, a separate rectifier tube is employed in the power supply which replaces the batteries. In some sets, the audio output tube is also replaced with a more *powerful* tube when the receiver is operated from AC-DC power.

Single Battery Portables. In 1941, combination portables were manufactured which obtained all the power necessary for the operation of the receiver from a 2 volt built-in rechargeable battery. The tube filaments are heated directly by the battery voltage, while the necessary high voltage for the screen and plates of the tubes is furnished by a synchronous vibrator used in conjunction with a step-up power transformer and associated filter circuit. Provision is incorporated to charge the battery directly from the house current without removing the battery from the receiver circuit. The condition of the battery may be judged by observing floating balls which serve as a hydrometer.



Special Requirements for Auto Sets. Primarily, automobile radio receivers are different from home sets in that they incorporate power supplies of the vibrator type designed for operation from a six volt source. Please notice this fact in the circuit above. Type 84 rectifier tube is often used. Type 0Z4 tube is used in sets where current drain must be conserved.

Since the antenna used with auto sets is necessarily small, a pre-selector R.F. stage is incorporated. One or two I.F. stages are used.

Because of vibration and movement of the automobile, the components of the radio must be carefully mounted in place. Usually, the entire radio receiver is housed in a metal container which mounts behind the dash and has the control dials placed on the dash.

Before 1938, identical radios were intended for all makes of cars. The dash control was supplied for the particular car in which the radio was to be mounted. Radios of this type were also made in more recent years and supplied with a universal control which could be attached to the dash of any car. The public preferred, and justly so, the new crop of auto radios made for specific automobiles. Space for these radios was provided by the automobile designers on the dash. These more modern radios included push-button tuning since this convenience permitted the selection of the wanted station without removing attention from the road.

Modern auto radio antennas are most often of the buggy whip type. The best results are obtained when the antenna is mounted clear from the body of the car, and as far away as possible from the engine.

In estimating the probable time required to repair an auto radio, be sure to allow ample time for the task of taking the radio out of the car and placing it back in place. This work may prove the biggest part of the job.

LESSON 53

Service Case Histories

The service hints presented in this lesson have been reprinted from "Service Hints," Volumes 2 and 3, compiled and published by *Sylvania Electric Products, Inc.* Due thanks is extended to this firm for their fine cooperation.

BENEFIT THROUGH THE EXPERIENCE OF OTHERS. Similar faults often develop in a particular model radio receiver. This is to be expected. With years of use, a fault is bound to arise even in the finest radio. The weak *link* may be a condenser, a certain tube, or some other part, or a fault in the wiring or the alignment. The experience of other radio servicemen with the model radio you may be servicing may suggest the probable fault and lead you directly to the trouble. Case histories are helpful to diagnose the fault and carry out the repair in the minimum of time. Extensive testing is eliminated on many jobs. You should always refer to this lesson before beginning work on a broadcast type radio receiver.

Many of the hints given in the case histories presented below will apply to other radio receivers and should be studied carefully by you. Usually the model number and manufacturer's name can be found on a metal plate attached to the chassis of the radio or on a tag inside the cabinet. The case histories are listed below in alphabetical order by the correct manufacturer name, followed by the model number. This information is given in the narrow column at the left; the case history for the radio model mentioned is alongside in the wider column.

All American 70, 73, 75...............

Hum trouble frequently has been traced to a defective condenser connected across the tuned choke coil in the power unit. Replace with a 0.1 mfd., 600 volt, condenser.

Atwater Kent 37, 38, 40...............

Some of these sets as well as other makes will start with a very loud howl, and as soon as the 27 tube used as the detector heats, this action will stop. This can be eliminated by adding a resistor of about 50,000 ohms, ½ watt, connected between plate and cathode of this tube.

Atwater Kent 84.....................

If this set plays for an indefinite length of time and then breaks into oscillation *over* the entire dial, the trouble may be traced to the 60,000 ohm resistor in series with the grid conection to the oscillator tube, type 27.

Brunswick S-14, S-21.................

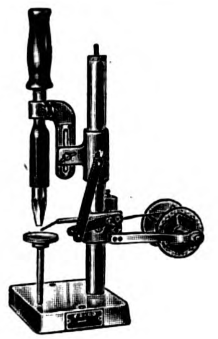
These sets use an R.F. choke as the primary winding of the second and third radio frequency transformers. These chokes are coupled to the secondaries with .00025 condensers. To greatly increase the volume without any loss of selectivity, remove these chokes and condensers and put on a primary winding of twenty turns. This can be done without removing the radio frequency transformers from the set. Use No. 26 or No. 28 double silk covered wire, and align the receiver.

Columbia (or Knight) SG-8	If this receiver breaks into oscillation when the volume is turned on, this is due to coupling existing between the last I.F. and detector stages. The most satisfactory way to make this set behave under such conditions is to insert a 5,000 or 6,000 ohm resistor in the grid circuit of the detector. Clip the short wire from the detector grid to the coil and put this resistor in place of it.
Crosley 30S	When this set gradually loses its volume and the rectifier tube overheats, test the large carbon resistor mounted on a small strip along the back of the chassis (brown with orange spot). This is a bleeder resistor and usually loses its resistance, increasing the current drain. It can be replaced with a 40,000 ohm, 5 watt resistor.
Crosley 124	Noisy and intermittent reception seems to affect all sets of this model that have seen much service. Even light jarring will cause the set to act up. The by-pass condenser block W22412, consisting of four .1 mfd. units, metal container common, is probably defective. Replace entire unit with four new condensers.
Crosley 706	If set fades and sensitivity is poor, remove two screws upon top of condenser tub. Remove brass bushing and washer, rear of condenser assembly shaft. Sandpaper and clean these parts, bend steel spring for more tension, tighten screws, and align variable condenser plates. Replace washer and bushing and re-check on oscillator. These condensers are not pigtailed, hence the fading, when the spring contact is dirty. To make permanent, add a pigtail lead.
Edison R-6, R-7.....................	Very pronounced rumbling or drumming sound present only when very low frequency bass is being reproduced. Commonly caused by voice coil striking the field housing at the bottom of voice coil passage. Remove the speaker head assembly and insert a thick cardboard washer to give voice coil more travel-distance.
Grunow 660, Chassis 6C............. **(General Household)**	A frequent trouble in this receiver is *mushy* reception. The set will pick up stations but the reception will be distorted. In every case of this kind, the .01 mfd. coupling condenser between the plate of the 75 tube and the grid of the 42, was leaky. Even if this condenser has a leakage of from 5 to 10 megohms, it will cause trouble. This unit is part No. 29453, mounted on the inside and at the bottom of the small terminal board which is on the left side of the chassis looking at the set bottom side up from the front. Replace with a 600 volt type.
Majestic 50, 52...................... **(Grigsby-Grunow)**	Motor-boating at all frequencies or a tendency to oscillate continuously on the higher frequencies, in this chassis is due either to a defective or wrong value grid condenser on the oscillator tube. The diagram specifies a .001 mfd., but many use .0005 mfd. By changing the .0005 to a .001, and substituting 50,000 ohms for the 100,000 ohms across it, the set gives very stable and improved results.
Majestic 90, 91, 92..................	Set, at short intervals, begins to cut in and out and the reception becomes very choppy. Check center-tapped resistor across 27 tube heaters for a corroded center tap. The total resistance is 1.6 ohms.
Majestic 490	Motor-boating is often caused by the electrolytic filters drying and changing in capacity.

National Carbon (Eveready) 50.......	A very satisfactory and economical repair can be made on this receiver whenever the high resistance section of the dual volume control is burned out or has a mechanical defect occur, by removing this section and placing a 50,000 to 75,000 ohm, 2 watt, fixed resistor in the same circuit. The other section of the dual control regulates the grid bias and provides ample control of the volume under all conditions.
Philco 16	Frequency drift; resolder all coil connections and rebalance. Oscillates too freely on short waves; check electrolytic condenser No. 30-2011. Cutting off with a subsequent widening of shadow tuner and then cutting back on again is caused by a defective 6A7 tube.
Philco 20	If set oscillates with volume control turned on full, connect a .05 mfd. condenser from chassis to the R.F. transformer side of the resistor in the B+ lead of the first R.F. tube.
RCA Victor R-7	The 14,000 ohm screen-grid voltage resistor and 8,000 ohm bleeder resistor in this set often change their values. This results in a loss of sensitivity and very poor tone. Replace these resistors with 1 watt wire wound units whenever this model comes into your shop.
Sparks-Withington Sets	In the older *Sparton* models, those with separate tuning units, often the complaint is: "Very broad tuning." This trouble is usually caused by shorted turns on an R.F. coil. In this case, the R.F. assembly should be carefully removed from its box, the shorted turns located, separated with a fine needle, and painted with repair cement for insulating purposes.
Stewart-Warner 102A	With symptoms of very weak and distorted reception and only the local stations barely audible, look and check for an open or shorted fixed capacitor (0.1 mfd.) connected between the purple and yellow resistors on the resistor strip under the rear of the chassis.
Stewart-Warner 111, 115............	Tunable hum may be caused by condenser No. 15 opening. If you change condenser No. 34 in Stewart-Warner 111, be sure it is not wax or tar filled. This chassis stands on end and heat from the 43 tube will cause wax or tar to run down.
Transformer Corp. of America 220..... **(Clarion)**	Lack of reception in this receiver often can be traced to an open control grid clip wire leading to the 24A detector-oscillator tube. The connection between the clip and the tuning condenser is a short piece of 1,000 ohm wire inside a sheath. An open cannot be noticed or found except by a complete analysis of the receiver. The trouble can be remedied by using a 1,000 ohm, ½ watt resistor in series with the control grid clip to the condenser.
U. S. Radio & Tel. 8.................. **(Apex, Gloritone)**	Lack of volume throughout the entire broadcast band may be caused by the 25 mfd., 150 volt, electrolytic condenser across the bias resistor. This condenser should be replaced. You will find this condenser between the power transformer and R.F. coil cans. Intermittent operation accompanied by oscillation, the dial being off calibration, is probably due to the .01 mfd., 400 volt, oscillator circuit coupling condenser.
U. S. Radio & Tel. 27................	Oscillation is caused by opening of .04 mfd., by-pass condenser in cathode circuit of the 24A's.
Zenith 705, 707, 711................	Intermittent reception usually can be traced to the 5 mfd., 25 volt, electrolytic condenser on cathode of second detector socket.

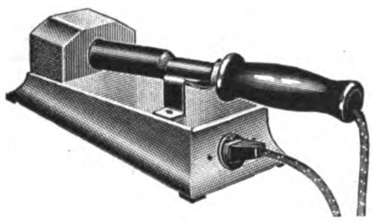
ESICO

REG. U. S. PAT. OFF.

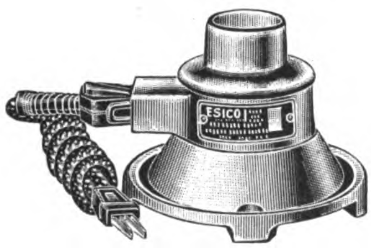


Illustrated is the ESICO 100 watt soldering iron. This is the most popular size for fast continuous soldering in radio factories. Also popular with service men for the reason that it comes to heat quickly due to the fairly high wattage for a small iron. It is not recommended for use where the iron is to be left on the circuit and will have long periods between actual soldering applications. A smaller wattage iron is required in this instance, or this iron should be placed in a temperature regulating stand to prevent it from overheating. Irons are obtainable with tips which screw into the element core, or with so called plug tips which slide into the element core.

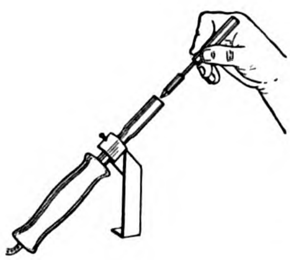
The machine on the left is the ESICO Spot Soldering machine. It is operated with a treadle which advances the iron so that it comes down and makes contact with the solder and the part to be soldered. The solder advances as the iron moves upward and is in position for the next operation.



The ESICO temperature control stand cuts the iron in and out of the circuit thus preventing it from overheating when lying idle. Soldering irons must be made with a surplus of heat capacity in order to withstand the drain on them when they are bringing the work to be soldered to temperature. Consequently, they can not be left on the circuit continuously without heat being taken from them.



ESICO solder pots are used for dipping the ends of wires, lugs, etc., for the purpose of tinning them prior to soldering into assemblies.



The illustration to the left shows an ESICO plug tip soldering iron, held in a bench bracket and a small pencil soldering copper being removed from it. This very small pencil iron is used for soldering extremely small items. It is a popular method of soldering in electric meter manufacturing establishments, where connections often are soldered under a magnifying glass. This is due to the fact that the wires being soldered are very small and minute quantities of solder are applied.

ELECTRIC SOLDERING IRON CO., Inc.

2644 West Elm St. **Deep River, Conn.**

SURFACE ANALYZER

(*Continued from page* 330)

Vertical motion is due only to the surface irregularities.

The amplification is equivalent to magnification of the irregularities which produced the initial crystal voltage.

The tracer point is mounted in a tubular lever arm and is protected from mechanical damage by a steel finger which carries the positioning shoe. This positioning shoe rides over a relatively large area of the surface under test and establishes a reference level for the tracer point and also supports the weight of the pickup arm. The tracer point is coupled to a quartz crystal element by mechanical linkage in such a manner that any vertical motion caused by the surface irregularity will place the crystal under stress. The crystal generates a voltage which is directly proportional to this stress.

CALIBRATING AMPLIFIER. A two stage amplifier is employed to supply the necessary gain (magnification) between the pickup and the direct inking oscillograph. A calibrated attenuator is included in the input circuit to provide various degrees of overall magnification of the surface irregularities so that they may be readable on the chart. A calibrating circuit is also included to supply a *test* voltage for adjusting the amplifier gain for accurate correlation with the pickup sensitivity.

DIRECT INKING OSCILLOGRAPH. The oscillograph unit, shown in the left part of the photograph, is used to make a graphic record of the irregularities of the surface under test, as explored by the pickup tracer point and *magnified* by the amplifier. The oscillograph is equipped with a direct inking pen actuated by a crystal element which is thermostatically controlled for stabilization. The movements of the pen are recorded on a moving paper chart. The chart feed mechanism is driven by a separte synchronous motor.

ATMOSPHERE CHAMBERS

(*Continued from page* 342)

The radio equipment may actually be operated within the chamber for a period of time.

Many unusual things happen to radio circuits at these temperatures. For example, resistors show much lower resistance values, and certain types of plastic insulation become brittle and crack.

multiple glass sections, sealed to prevent interior condensation, and present a clear view of the working space under all interior and exterior atmospheric conditions.

For electrical connections suitable lead-ins are provided. Special stand-off insulators are provided for high frequency and high voltage connections. Means are also included for connecting air or water pipes since some radio equipment may impose these requirements. To make mechanical adjustments of the apparatus under test, small rotating shafts are installed and are manually turned from the outside. When rotary power must be introduced, a small stainless steel shaft is used with a special packless vacuum seal.

In majority of standard units of this type, the pressure is controlled from atmospheric to that equivalent to 50,000 feet of altitude. Rate of pressure change is governed by the size of vacuum pump employed. The vacuum gage mounted on the outside is calibrated in feet of altitude.

Extreme temperature variations from —40° to 150° Fahrenheit may be obtained. The refrigerating effect is obtained by the evaporation of Freon or by circulation of an organic solvent precooled with dry ice. When mechanical refrigeration is used, single stage compression is employed for temperatures down to —40°, while below this level, multiple stage cascading is employed.

Heating of these units is accomplished by electric air-heaters mounted in a vigorously recirculated air stream. The desired humidity is produced by spraying a small amount of water into the air stream. The various conditions created in the test chamber are controlled from the outside and are shown or recorded on suitable gages.

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MODEL 542
Pocket Multimeter

Supreme Model 504-A—A combination tube, battery, condenser, and set tester. This instrument incorporates a unique switching arrangement whereby the operation is greatly simplified. When used as a set or condenser checker, the test leads do not have to be moved from two pin jacks. This simplifies and speeds up the operation. A telephone index type roll chart is incorporated with instructions for setting each control for all type tubes. Only one of each type socket is required, thus eliminating the possibility of tube damage by placing the tube in the wrong socket. As a multimeter the instrument can be used to measure from .1 to 2500 volts D.C.; .1 to 1000 volts A.C.; 10 microamperes to 10 amperes D.C.; .1 ohm to 20 megohms; and .1 to 1000 output volts.

Supreme Model 542 — A small pocket multimeter is indispensable for radio repair work. The Model 542 incorporates a 200 microampere meter which extends the usefulness of the small tester. The following measurements can be made with the Model 542: D.C. current from 5 microamperes to 150 milliamperes; D.C. voltage from .1 volt to 1500 volts; A.C. voltage from .1 volt to 600 volts; Resistance from 1 ohm to 2 megohms; Decibels from —6 to +50.

SUPREME INSTRUMENTS CORPORATION, GREENWOOD, MISS., U. S. A.

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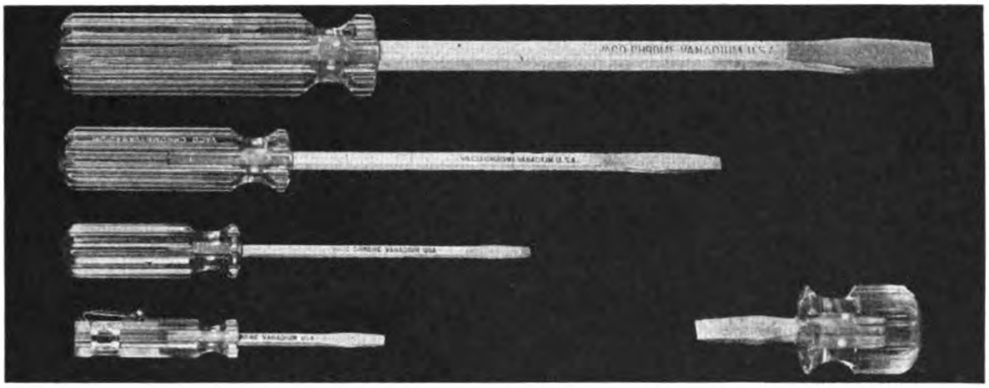

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Vaco screw drivers recommend themselves for one very simple but important reason. Whereas many manufacturers of tools consider screw drivers more or less of a "minor" department of their business, the makers of Vaco drivers are "screw driver" people. They have developed their product down to a fine point, actually studying the needs of every field they cover and—as nearly as possible—building "stock" drivers to take care of all needs.

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Vaco Products Company, 317 E. Ontario St., Chicago, Ill.

MANUFACTURERS OF

AMBERYL LIFETIME, CHROME VANADIUM, SPIN HEX, PHILLIPS, VACOLITE and RED FLASH NEON SCREW DRIVERS

INDEX, VOLUME THREE

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